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THESIS

MILITARY APPLICATION OF NETWORKING BY TOUCH IN COLLABORATIVE PLANNING AND TACTICAL ENVIRONMENTS

by

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September 2007

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Human Area Networks represent an emerging field of communications technology with the potential to offer significant advantages to military operations. This thesis explores and defines Human Area Networks (HAN) and addresses how HANs relate to existing network topologies as well as the various terminologies associated with HANs. The focus of research addresses the notion of "touch" as an event and attempts to relate the various interpretations of "touch" networking to HANs while describing a preliminary architecture through the use of multiple scenarios and use cases, quality attributes, and functional requirements. Additionally, this thesis explores the opportunities associated with one particular implementation of HAN: Intrabody Communications (IBC), and proposes an implementation plan for conceptual IBC devices. Ultimately, this thesis demonstrates the potential value of IBC and HANs in a Joint Tactical scenario with recommendations for iteratively evaluating the techniques, tactics and procedures (TTP) in an incremental manner that seamlessly evolves with technology advancements.

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MILITARY APPLICATION OF NETWORKING BY TOUCH IN COLLABORATIVE PLANNING AND TACTICAL ENVIRONMENTS

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Human Area Networks represent an emerging field of communications technology with the potential to offer significant advantages to military operations. This thesis explores and defines Human Area Networks (HAN) and addresses how HANs relate to existing network topologies as well as the various terminologies associated with HANs. The focus of research addresses the notion of “touch” as an event and attempts to relate the various interpretations of “touch” networking to HANs while describing a preliminary architecture through the use of multiple scenarios and use cases, quality attributes, and functional requirements. Additionally, this thesis explores the opportunities associated with one particular implementation of HAN: Intrabody Communications (IBC), and proposes an implementation plan for conceptual IBC devices. Ultimately, this thesis demonstrates the potential value of IBC and HANs in a Joint Tactical scenario with recommendations for iteratively evaluating the techniques, tactics and procedures (TTP) in an incremental manner that seamlessly evolves with technology advancements.

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ACRONYMS AND ABBREVIATIONS

AO	Area of Operations
AP	Access Point
AAR	After Action Review
ATL	Assistant Team Leader
BAN	Body Area Networks
BFC	Biometric Fusion Center
BPS	Bits Per Second
BPSK	Binary Phase Shift Keying
C2	Command and Control
CENETIX	Center for Network Innovation and Experimentation
COA	Course of Action
CMOS	Complementary Metal–Oxide–Semiconductor
CPC	Collaborative Personal Communicator
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DoDAF	DoD Architecture Framework
DSL	Digital Subscriber Line
DSS	Decision Support System
DSSS	Direct Sequence Spread Spectrum
EBXML	Electronic Business Extensible Markup Language
EO	Electro-Optic
EWALL	Electronic Card Wall
GIR	Generic Intelligence Requirements
GPS	Global Positioning System
HAN	Human Area Network
HANNA	HAN Nomadic Agency
HANND	HAN Nomadic Device

HCI	Human Computer Interface / Human Computer Interaction
HED	HANNA Enabled Device
HID	HAN Interface Device
HIT	HAN Interaction Table
HMI	Human Machine Interface
HSI	Human Systems Integration
HVT	High Value Target
I & W	Indications and Warnings
IAO	Information Awareness Office
IBC	Intrabody Communications
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IR	Infrared
IrDA	Infrared Data Association
ISM	Industrial, Scientific, and Medical
ISO	International Standards Organization
ISP	Internet Service Provider
JIO	Joint Information Operations
JOPES	Joint Operation Planning and Execution System
JPEG	Joint Photographic Experts Group
JTRS	Joint Tactical Radio System
KVA	Knowledge Value Added
LAN	Local Area Network
LCD	Liquid Crystal Display
LLNL	Lawrence Livermore National Laboratory
LOS	Line of Sight
MAC	Media Access Control
MAN	Metropolitan Area Network
MCPP	Marine Corps Planning Process
MIO	Maritime Interdiction Operations
MIS	Management Information System
MIT	Massachusetts Institute of Technology

MMI	Man-Machine Interface
MMS	Multimedia Messaging Service
MOP	Measure of Performance
MPSIDS	Man-pack Secondary Imagery Dissemination System
MSK	Minimum Shift Keying
MSST	Marine Safety and Security Team
NCO	Network Centric Operations
NLOS	Non Line of Sight
NOC	Network Operations Center
NPS	Naval Postgraduate School
NTT	Nippon Telephone and Telegraph
NVG	Night Vision Goggle
OFDM	Orthogonal Frequency-Division Multiplexing
OP	Observation Post
OSI	Open Systems Interconnection
PAN	Personal Area Network
PC	Personal Computer
PIR	Priority Intelligence Requirement
PLA	Product Line Architecture
QA	Quality Attribute
R2P2	Rapid Response Planning Process
RFID	Radio Frequency Identification
ROI	Return on Investment
RTO	Radio Telephone Operator
RSS	Rich Site Summary
SA	Situational Awareness
SMS	Short Message Service
SOA	Service Oriented Architecture
SOCOM	Special Operations Command
SOF	Special Operations Forces
SOP	Standard Operating Procedure
TCP	Transmission Control Protocol

TL	Team Leader
TNT	Tactical Network Topology
TOC	Tactical Operations Center
TSAS	Tactical Situational Awareness System
TTP	Tactics, Techniques, and Procedure
UAV	Unmanned Aerial Vehicle
UHF	Ultrahigh Frequency
USB	Universal Serial Bus
USCG	United States Coast Guard
USMC	United States Marine Corps
UWB	Ultra-Wideband
VHF	Very High Frequency
VoIP	Voice Over Internet Protocol
WAN	Wide Area Network
WiFi	WLAN products based on the IEEE 802.11 standards
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
XML	Extensible Markup Language

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Andy Strickland

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I. INTRODUCTION

A. NEW NETWORKING PARADIGM

In 2007, The Department of Defense (DoD) spent $30.5 billion on the research, development, acquisition, and installation of communications equipment and information technology. Eight percent of this total investment supported programs that directly provided tailored information to individual users. In 2008, the total IT budget projects to spend $31.5 billion with only 7.2% allocated to the same resources, or roughly, $156.5 million less (FY2008 President's Budget Request). This extremely disproportionate distribution is disturbing, especially considering that end users of information systems in the DoD are typically human decision makers.

A back-of-the-envelope calculation shows that the modest data rates of modems one decade ago, or 56 kilobits per second (kbps), yielded approximately five pages of text every second (assuming an average word size of six characters at one byte per character, and a page length of 250 words). Pervasive networking speeds of today at 1.5 Megabits per second (Mbps) yield 128 pages of text every second. If one projects the trend that bandwidth doubles every 18 months (National Telecommunications and Information Administration), then in five years home networks will be connected to services capable of delivering 1500 pages every second.

$$\frac{1Byte}{character} \cdot \frac{6characters}{word} \cdot \frac{250words}{page} \cdot \frac{8bits}{Byte} = \frac{12,000bits}{page}$$

$$\frac{56kbps}{12000bits/page} = 4.67 pages/second$$

$$\frac{1.536Mbps}{12,000bits/page} = 128 pages/second$$

$$\frac{18Mbps}{12000bits/page} = 1500 pages/second$$

To place this in perspective, an individual could conceivably download the entire 2007 Encyclopedia Britannica set of 32,640 pages in just over 21 seconds (Amazon).

Data on technology growth rates is well documented. Figures 1-3 demonstrate historic technology trends pertaining to several vital metrics centered on size and performance. According to renowned technology inventor and author Ray Kurzweil, these graphs, all plotted on logarithmic scales, consistently reveal exponential trends. From the miniaturization of mechanical devices to processing performance and Internet bandwidth in bits per second (bps), technology is universally exploding at unprecedented, exponential rates. Mr. Kurzweil concludes that these technological trends will continue to make our devices, indeed every aspect of our lives, significantly more connected at faster rates with smaller components for less money, sooner than previously imagined (Kurzweil 2005).

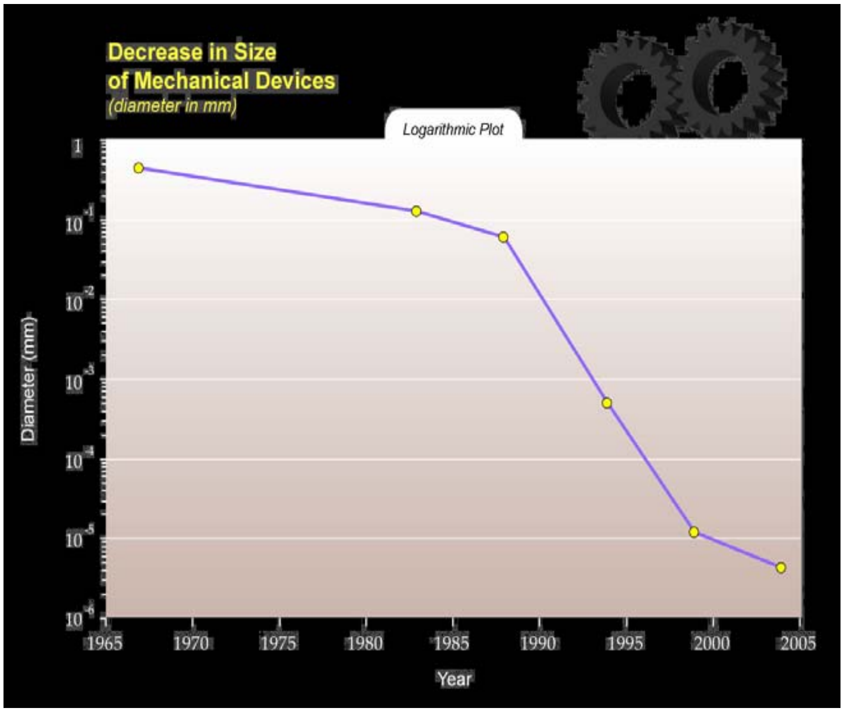

Figure 1. Decrease in Size of Mechanical Devices (From Kurzweil *The Singularity is Near*, p 82).

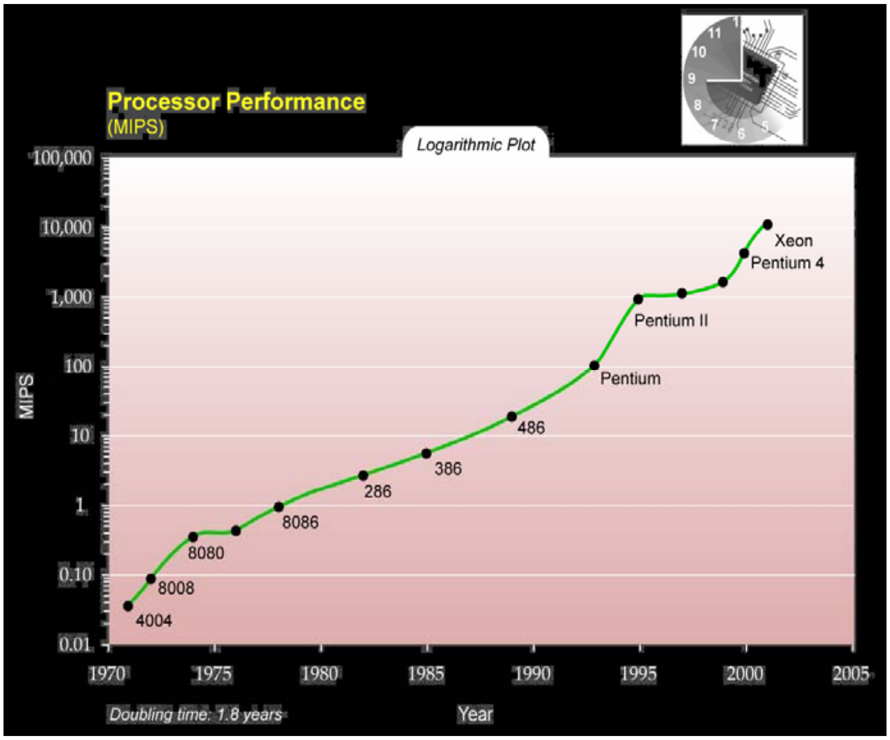

Figure 2. Processor Performance (From Kurzweil *The Singularity is Near*, p 64).

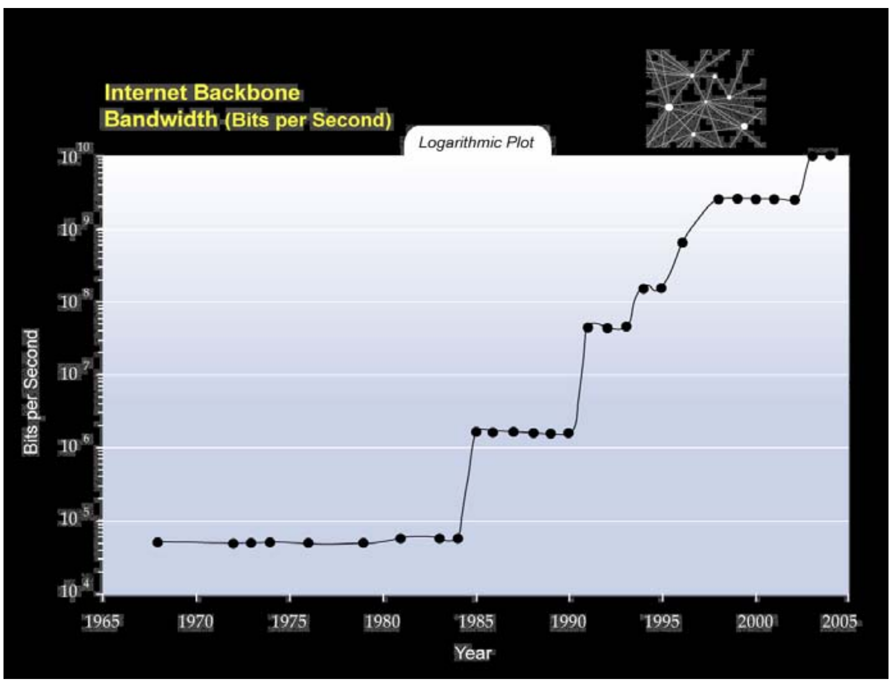

Figure 3. Internet Backbone Bandwidth (From Kurzweil *The Singularity is Near*, p 81).

These statistics excite Internet Service Providers (ISP) and other vendors whose profit margins increase through sales of higher capacity services but they present daunting scenarios for human decision makers at the heart of the network. For example, processing, or understanding, four plus pages per second, let alone 1500 pages, far surpasses a normal user's ability to comprehend. The volume is simply too much to conceivably handle and it becomes even more difficult when one considers that most sessions exceed one second in duration. Faced with this dilemma, DoD IT acquisitions programs should shift resources toward the individual user level and focus on discovering rapid, evolutionary approaches for filtering four to 1500 pages per second into knowledgeable forms relevant to the user. Unless we collectively develop technologies that enable users to filter and process exponentially increasing amounts of data at faster rates, humans risk living and operating in over-saturated environments of unmanageable masses of data being forced upon them.

As illustrated in Figure 4, varying layers and scales of networks surround users. The most precious realm to the average person, however, is that with which he interacts most frequently. Although the Wide Area Networks (WAN) and Metropolitan Area Networks (MAN) are fundamental components enabling global interconnectivity, the most frequent impacts to an individual are realized in those regions proximate to him.

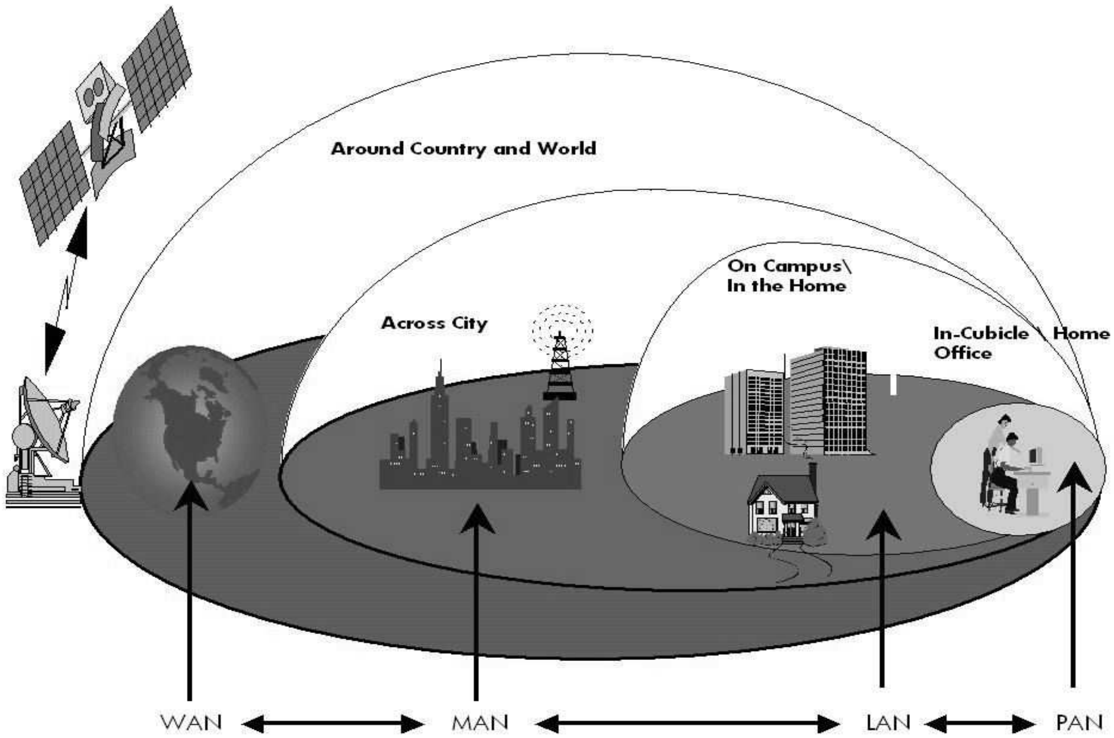

Figure 4. Computing Realms (From Hayes-Roth *Radical Simplicity* Figure 8.1.).

1. Human Area Networks as a New, "Adaptive" Computing Realm

Human Area Networks (HAN), not pictured in Figure 4 but existing within the Personal Area Network (PAN) bubble, seamlessly integrate the capabilities of modern technology to the individual while taking advantage of the superior speeds, processing, and storage associated with the higher level network envelopes. For example, consider the following devices a technology-enabled person might carry: cellular phone, Global Positioning System (GPS), digital video and still cameras, media storage, and perhaps a form of remote vehicle access. Then take into account the high level services these devices provide for users: cellular voice communications, Short Message Service (SMS), Multimedia Messaging Service (MMS), Media Storage/Access, Internet Access (and all associated web-services including Voice Over Internet Protocol (VoIP), financial management, etc), navigation and directions, WiFi, WiMax, Bluetooth, Electronic-mail (E-mail), calendar/ date book assistants, address book, document editors, and Rich Site Summary (RSS) readers, to name a few.

Now, imagine an environment where the above devices and services converge to form adaptive solutions that provide tailored functionality based on the individual's preferences and current context. Multiple devices providing redundant features are streamlined, leaving the remaining components to receive up to date information unrealized by any one previous device. The revolutionary functionality afforded by touch networks serves as the platform to deliver value in such a system. Configurable devices, worn on the person, conform to the user's preferences by learning through the physical interactions within that user's environment. File sharing is accomplished with a graze of the finger. Ultimately, the world is customized to the user's comfort level as the device continuously updates his preference profile. The following scenario illustrates the potential value of such devices.

B. "HAN" SCENARIO: MILITARY

1. Mission Planning and Execution – Present

Sergeant (Sgt) Snuffy's Platoon Commander enters the Reconnaissance Platoon tent to inform his 1st Team Leader (TL) of an upcoming Reconnaissance and Surveillance (R&S) mission for a Division High Value Target (HVT).

Sgt Snuffy ventures over to the Battalion Operations compound and enters the mission planning space with his Captain to commence preparations for the upcoming mission. The two Marines sit down at a table and begin the Marine Corps Planning Process (MCPP) by analyzing the tasks from higher headquarters (HHQ). They write down the tasks issued from higher as "specified" and number them on a piece of paper. Based on personal experience and previous patrols in the area, the Marines then devise a list of "implied" tasks from memory. They debate which items are actually tasks versus which ones are Standard Operating Procedure (SOP), the latter of which is not, by doctrine, included in this task list. After 20 minutes, the list is whittled to five implied tasks.

The Operations Chief, a Marine with 20 years of reconnaissance experience, strolls by and can't help but glance at the "completed" list. He suggests three more relevant tasks the two planners neglected to include. The Marines circle those tasks which they deem "essential" for mission success and begin to compose a mission statement. Fifteen minutes and three drafts later, the Platoon Commander approaches the Operations Officer for approval on the draft mission statement. A few changes are made before he receives approval. A Lance Corporal (LCpl) then transcribes the mission statement next to 1st Team, 1st Platoon on a wall-mounted dry-erase board.

The intelligence section sits adjacent to the operational mission planning area and marks the next stop for the Platoon Commander and his TL. The two Marines knock on a locked door before being met by one of the Intelligence Analysts who recognizes both of the Marines and grants them access. After signing a log-in sheet near the entrance, the two link-up with the unit Intelligence Officer (S-2) and explain their upcoming mission. The S-2 asks for the target number and grid coordinate as he walks over to a map hanging on the wall. He then orders his chief analyst, a Staff-Sergeant (SSgt), to dig-up the electronic target package associated with this location. The SSgt turns on a projector connected to his laptop and projects some imagery to a screen hanging on the wall adjacent to the map around which everyone is gathered. The S-2 pulls up a complex collections matrix spreadsheet on his laptop and uses the Control + F feature to rapidly locate the row featuring this particular target number. After locating the cell, he reads the Priority Intelligence Requirements (PIR) next to it as Sgt Snuffy quickly scribbles them down in a notebook, just underneath the mission analysis notes he made over an hour ago. The S-2 then tasks his SSgt to e-mail the Division Intelligence (G-2) Collections Chief and ask what other assets will be flying in the Area of Operations (AO) on the day of the recon's team insertion. The S-2 also seems to recall some Human Intelligence Teams (HUMINT) operating in the vicinity of the target site but waits to confirm it with the Division G-2. The Marines review the task list and PIRs to ensure all members retain a comprehensive understanding of what needs to be accomplished during this R&S mission. The TL is then instructed to report any changes to the composition, disposition, strength of adversaries approaching, surrounding or on the target site as priority.

The Platoon Commander and Sgt Snuffy continue their face-to-face coordination with additional entities including logistics, fire support, aviation, and communications. Along the way, Sgt Snuffy's Assistant Team Leader (ATL) asks for any "gouge" so he can continue preparing the rest of the team for the mission (the ATL's responsibility includes supervising the team's logistical preparedness). Sgt Snuffy opens his notebook and begins sharing the information with his ATL, who furiously scribbles some notes down into a similar notebook of his own. After several minutes, the two depart.

As the Recon Team departs friendly lines, the Radio/Telephone Operator (RTO) picks up the handset of a Very High Frequency (VHF) radio that he forgot to turn-on and function check. The patrol halts while the RTO opens a notebook, locates the correct frequency, loads it into the radio and attempts to call in the codeword indicating "Team 1 departing friendly lines." As the team approaches their Observation Post (OP), they employ room-clearing Tactics, Techniques and Procedure (TTP) to ensure the building is empty before occupying a vantage point on the top floor. The six-man team enters and splits into two groups of three Marines, one going left, the other right. The hallways and rooms are dark and they do not have a blueprint of the building's layout. The two teams converge at the end of a dark, maze-like hallway, weapons at the ready when the TL hears something around the corner. The other two Marines behind him take aim with their rifles. The TL initiates a near link-up SOP by flashing the Infrared (IR) light on his Night Vision Goggles (NVG); he detects a response from the other half of his team. Narrowly averting a fratricide incident, the 6 Marines link-up safely, confirm that floor is clear, and move on to the next level.

On the rooftop, a Marine observes the target site through the powerful scope-like lens of his Man Pack Secondary Imagery Dissemination System (MPSIDS). The Marine snaps a photo then ejects the memory card from his camera, plugs it into a Universal Serial Bus (USB) adaptor and inserts the adaptor into a Tough-book laptop. After a few seconds, the external device is recognized. A window appears containing Joint Photographic Experts Group (JPEG or .jpg) files for the Marine to review. He scans some thumbnails, locates the photo he just took, moves it to a directory on the hard drive, and opens a photo-editing application. The Marine then reads his GPS and inserts a text box into the lower left corner of the image where he types in his current position. He then uses the drawing tool to add a north-seeking arrow to the image. Finally, he opens an e-mail application and selects the S-2 address from a contacts folder. A new message opens and a few clicks of the mouse later, the .jpg image is attached and sent.

2. Mission Planning and Execution – Future

A Platoon Commander enters the tent of his Reconnaissance Platoon to inform his 1st TL, Sgt Snuffy of an upcoming R&S mission for a Division HVT.

Sgt Snuffy ventures over to the Battalion Operations compound and enters the mission planning space with his Captain to commence preparations for the upcoming mission. He sits down at a table and **touch**es the screen of a laptop which instantly authenticates his identity through a device connected to his body and loads a specific mission planning profile tailored to the TL. The application presents a couple of options, one of which displays the mission number for his current assignment. He **touch**es this option which activates an automated MCPP assistant complete with drop-down menus. Sgt Snuffy clicks on Step 1: Mission Analysis, which displays a top field containing several specified tasks in bold and a second field listing suggested, implied tasks. The top field cannot be manipulated, as these were assigned by HHQ, whereas the second field, populated by the current mission type combined with Sgt Snuffy's past experience in similar missions (retrieved from the device on his body), and adjacent unit After-Action-Reports (AAR), allows the user to select and/or add tasks. After finishing this task analysis, remaining tasks deemed "essential" populate a third field where Sgt Snuffy and his Platoon Commander review the prioritized order before accepting them. Sgt Snuffy **touch**es "Accept" upon which a mission statement is automatically generated. The system also produces a list of potential resource shortfalls as well as a recommended list of Information Requirements. The data is then transferred from a sensor on the mouse to Sgt Snuffy's device. He releases his finger from the mouse and after a few seconds, the system logs him off.

The intelligence section sits adjacent to the operational mission planning area and marks the next stop for the Platoon Commander and his TL. Sgt Snuffy authenticates his identity to a **touch** screen panel outside of a locked door which makes a connection to his device, authenticates his identity, confirms the status of his security clearance and allows entry to the classified intelligence space. A laptop screen similar to the operational mission planning space awaits Sgt Snuffy's **touch**. As the system uploads the Marine's profile, it verifies and updates the status of his mission by coordinating with his personal device. A tailored list of PIRs appears based on the mission parameters previously confirmed in operations, suspected target location/description and by cross-referencing a dynamically populated, regional Generic Intelligence Requirements (GIR) database. Additionally, a list of standing products (imagery, three-dimensional fly-through videos, etc) appears to the right of these requirements. Underneath the links to these products, a third field contains a list of the projected tactical and theater-level collections assets that will be operating in Sgt Snuffy's AO including additional R&S teams, micro-Unmanned Arial Vehicles (UAV) and HUMINT teams, among others. This list is not comprehensive, however, as it only contains assets equal to the level of Sgt Snuffy's clearance (originally detected upon login). After reviewing this personalized data (only some of which is transferred to Sgt Snuffy's device due to classification and sensitivity), they are met by an S-2 to go over details and answer questions. This meeting, combined with the task/mission analysis confirms what information is still needed and considered "valuable" to the Recon team ***during*** the conduct of their mission. Changes in the composition, disposition, strength of adversaries approaching, surrounding or on the target site are noted as priority and tagged to be electronically disseminated to the entities employing other collections assets in support of the team's mission. Once Sgt Snuffy's team has departed friendly lines, only the "deltas" will be reported.

This pattern of rapid, automated and tailored mission planning continues as the Marines coordinate with logistics, fire support, aviation [insertion] and communications entities. At points along the way, Sgt Snuffy meets with his ATL and via a handshake, the two exchange data. The ATL, responsible for supervising the team's logistics preparedness, receives updated lists of recommended mission items including: pyrotechnics, ammunition amount and type, optics, batteries (based on estimated mission duration and environmental conditions as well as the number of devices requiring batteries). Not fully confident in the computer's recommendation, the ATL hides two additional batteries in the bottom of his rucksack and continues supervising his team's readiness.

As the Recon Team departs friendly lines, the RTO **picks up** the handset of a Joint Tactical Radio System (JTRS) he forgot to turn on and function check, and attempts to call in the codeword indicating "Team 1 departing friendly lines." An electrode interface on the handset sends a tiny current to the RTO's personal device which uploads the frequencies for the team's specific mission and the communications transaction occurs, albeit 10 seconds late. As the team approaches their OP, they employ room-clearing TTP to ensure the building is empty before occupying a vantage point on the top floor. The six-man team enters and splits into two groups of three Marines, one going left, the other right. The hallways and rooms are dark and they do not have a blueprint of the building's layout. The two teams converge at the end of a dark, maze-like hallway, weapons at the ready when the TL receives a slight **vibration** in the upper right quadrant of a vest he is wearing. The familiar tactile sensation alerts him to the presence of nearby friendly forces. He gestures to the others to lower their weapons. The six Marines link up safely, confirm that floor is clear, and move on to the next.

On the rooftop, a Marine observes the target site through the powerful scope-like lens of his MPSIDS. The Marine snaps a photo and **touch**es a menu dial on the back of his camera to tag the photo for e-mail. His personal device populates the Liquid Crystal Display (LCD) with a list of addresses, one of which belongs to the S-2. He marks the photo with another **touch**. As a downsized version of the file transfers to the Marine's device, the GPS on his vest sends his current location and orientation (East, 87 degrees magnetic) to be encoded as metadata on the image file. The Marine **touch**es the mouse-pad of his Tough-book laptop (connected to a JTRS) and opens the e-mail application. A message addressed to the S-2 automatically pops up with the photo he just took as an attachment.

C. THESIS QUESTIONS

Very little data exists on the emerging field of HANs, urging further study on the potential impact of this technology. This thesis ultimately seeks credible solutions for Department of Defense IT Acquisitions decision-makers for the following three questions:

1. How and Where Should the Department of Defense (DoD) Employ "Networking By Touch" Technologies to Maximize Individual User Efficiency and Effectiveness?

Scenarios and mini use-cases illustrate the potential value of HANs in military contexts by objectively comparing the difference between present and anticipated states of this technology. Employment of HANs ultimately rests in a comprehensive analysis that incorporates the following: defining the user community, agreeing on what determines "efficiency and effectiveness," and the maturity level of the technology itself.

2. What are the Key Architectural Components of HAN and "Networking By Touch?"

More than just futuristic tools of convenience, a Touch Network Product Line Architecture (PLA) would ensure standardized software components capable of maintaining interoperability through common communication protocols while maximizing the reuse of those same components. At the center of this architecture rests the human fulfilling roles of decision-makers, war-fighters or some other function, each operating in varying contexts with potentially different rule sets.

The ground-breaking architecture proposed in this thesis attempts to clarify trade-offs between the defined quality attributes that span these diverse contexts while maintaining the user's centrality in the overall functionality of this technology. Scenarios and mini use-cases are employed to further illustrate these issues. As a novel architecture for an emerging technology, this proposal is not a finished product, but rather a foundation from which to evolve while iteratively evaluating future modifications as the technology matures.

3. What Implementation Strategy Maximizes the Value of "Touch Networks" While Ensuring Seamless Integration and Long-Term Success in the Existing DoD Networking Architecture?

Innovative technologies, still in developmental phases, stand a greater implementation success and survival rate when managed under an incremental, evolutionary approach (Hayes-Roth, February 14, 2007). The conclusion of this thesis proposes a realistic process for implementing and evaluating these technologies in an iterative fashion while simultaneously modifying their potentially evolving requirements. Ideally, this is all done under the cognizance of a recognized, qualified, Chief Architect in an existing technological test-bed environment. Acquisition and production risks are then mitigated by cyclically validating these system requirements and quality attributes, as outlined in our architecture, in order to adequately satisfy end-user requirements through the continuous improvement of end product(s) before they are mass produced.

D. THESIS ORGANIZATION

Chapter I proposed justification for pursuing the innovative, and potentially disruptive, technology of Networking by Touch. A military scenario illustrated deltas between "As-is" and "To-be" technological solutions worthy of exploration in order to maximize individual users' efficiency and effectiveness in an ever-evolving “Me-Centric” environment (Hayes-Roth 2003). The thesis questions established a foundation for developing technology solutions that bridge the gap between present realities and future possibilities.

The remaining chapters of this thesis are organized as follows:

Chapter II explores the notion of shifting the network to the human. It contains a synopsis of existing and notional network topologies including variations of Human Area Networks. Additionally, Chapter II explores current implementations of HANs, provides a notional classification scheme, and a proposed HAN ontology.

Chapter III describes a system configuration and architecture including proposed requirements analysis, network architecture, system architecture, system functional and quality attributes, and enabling applications.

Chapter IV proposes an implementation plan for this architecture using the Maritime Interdiction Operation test bed environment.

Chapter V records our conclusions and recommendations for future research with the intent of provoking further student and faculty interest in the iterative, formal evaluation of these emerging technologies.

II. SHIFTING NETWORKS TO THE HUMAN

A. DECISION MAKING IN THE INFORMATION AGE

Decision-making bears life or death consequences across the spectrum of military operations. Less severe outcomes might be simple matters of convenience in civil applications. Regardless of the scenario, humans routinely engage in a sense-decide-act process forming continuous feedback loops from one decision to the next. While technology provides tools to enhance our sensation and perception, the human decision-maker remains central to the entire process.

1. A Model for Efficient Thought

Elaborating on this decision-making theory, Dr. Rick Hayes-Roth proposes the concept of "Efficient Thought" comprised of eight separate, sequential steps capable of operating in parallel.

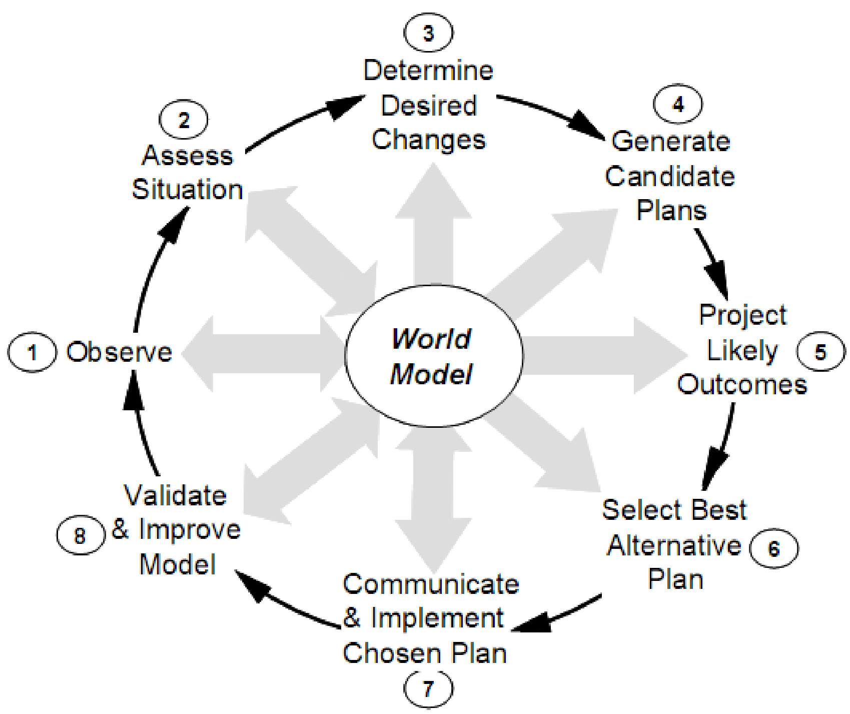

Figure 5. Efficient Thought (From Hayes-Roth *Hyper-Beings* Figure 2.)

In his model, the nucleus, or "World Model," acts as a knowledge-referral "hub" that decision makers use to interpret events, devise courses of action (COA) for improving their situation, and finally, to select the most attractive COA for execution. In Efficient Thought:

> The intelligent being (1) observes what's happening in the environment, (2) assesses the situation for significant threats and opportunities, (3) determines what changes would be desirable, (4) generates candidate plans for making those changes, (5) projects the likely outcomes of those plans, (6) selects the best plan, and (7) communicates that plan to key parties and implements it. Throughout, the intelligence being (8) validates and improves its model. The model supports all eight activities, although only steps 1, 2, 7 and 8 directly update and modify the model
>
> (Hayes-Roth 2006, 59)

The concept of "Efficient Thinking" considers the things that matter most for success and relies heavily on the human's learning ability to improve future outcomes. In order to use the best knowledge and reasoning processes to achieve optimal results, humans must be able to swiftly collate and evaluate ever-increasing amounts of information and do it at faster speeds than they did yesterday. The "memory dichotomy" dilemma human beings inevitably face rests in the extreme divergence between exponentially increasing technology, consisting of faster processors, more memory, and larger hard drives at one end, and human memory, which has historically remained on a linear plane at the other. Psychologist George Miller referred to this cognitive limitation as the "Magical Number Seven" (Miller, *The Magical Number Seven, Plus or Minus Two*) which states that the confines of human immediate memory rest somewhere around seven elements, plus or minus two.

2. Knowledge-Driven Decision Support Systems

Efficient Thought provides a framework for Decision Support Systems (DSS) Engineers who conceive and develop automated methods to rapidly filter and convert quagmires of data into tailored, informative and useable formats. The end result of a good DSS should deliver value in the form of improved, relevant options for decisions aimed at specific human audiences. They manage the information overload problem through a combination of organizational decision-making theory and interactive computer system designs that synergistically minimize human cognitive loads throughout the process.

One such DSS is referred to as "knowledge driven" which provides "specialized problem solving expertise stored as facts, rules, procedures, or in similar structures" (Power 2002). Closely related to data-mining, this system type sifts through large amounts of data in search of data "content" relationships relevant to the user's query, or need, and converts this data into useable knowledge, which ultimately provides pertinent, realistic options from which to choose. Historically, the delta between data and knowledge fueled the divergence between man and machine due to: (1) over-abundant and ever-increasing amounts of available data and (2) imprecise definitions of "knowledge" as it related to the user. As information availability exponentially increases, understanding what constitutes "knowledge" for each decision maker becomes more critical yet remains extremely challenging. The variety of potential contexts further exacerbates the situation. It also provides insight as to why the information hierarchy receives so much attention in the DoD, particularly within the discipline of intelligence analysis.

3. Information Hierarchy Model

In March 2007, former Director of the Defense Advanced Research Projects Agency (DARPA) Information Awareness Office (IAO), Dr. John Poindexter, introduced a revised version of the data-information-knowledge-wisdom pyramid more relevant to the Knowledge-Driven DSS described above.

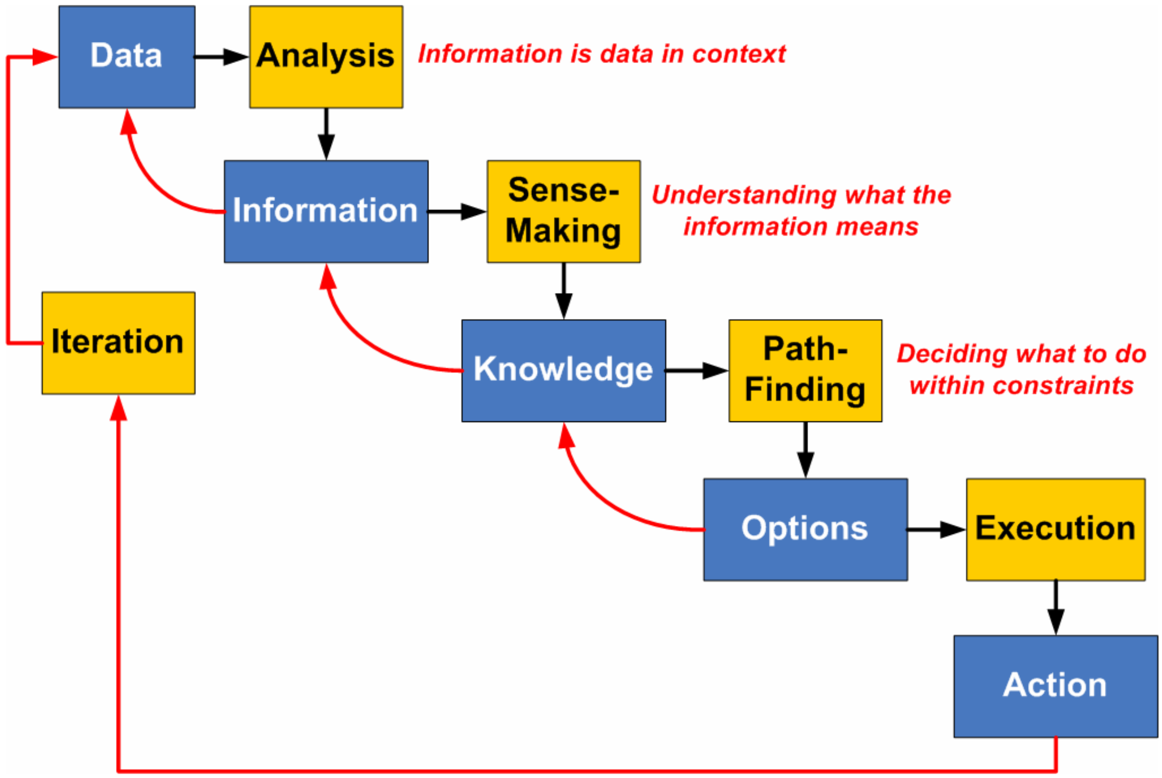

Figure 6. Poindexter: Sense-Making and Path Finding (After Cognitive Edge).

Poindexter's simplified model extracts "wisdom" from conventional information hierarchical diagrams and places the emphasis on knowledge with the additions of sense-making and path-finding. Sense-making refers to how humans understand the world given certain information so they can in turn act on it, while path-finding takes this comprehension of information and determines viable options from which we decide, then act, before the process repeats itself for our next decision (Cognitive Edge).

Concepts, systems and models like Efficient Thought, Knowledge-Driven Decision Support Systems and Sense-making to Path-finding reflect the human will to cope with the data glut produced by today's information revolution. Historically, people produced knowledge whereas today, knowledge pours in from robots, sensors and other devices creating exponentially more than our non-adaptive, over-tapped channels can handle (see Figure 7 for author's rendition of this phenomenon).

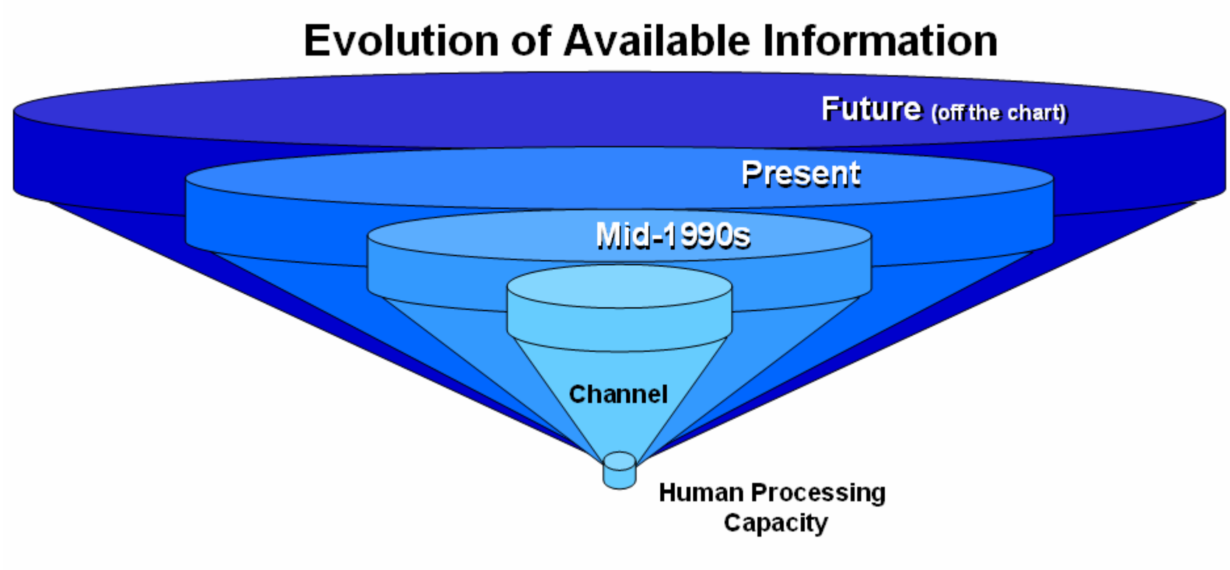

Figure 7. Information Age "Funnel"

Humans do not linearly adapt well to exponential changes in their environment. The Information Age sets ripe conditions for the quest to discover new, symbiotic relationships between man and machine that will enable humans to function with greater efficiency. The challenge remains to arrange existing and emerging technologies into better combinations that will lead to competitive advantages on the battlefield or in the marketplace. Implementing a Networking by Touch Architecture that automatically updates our World Model of Efficient Thought through intuitive, deliberate interactions with the immediate environment will push our race one step closer towards reaching effective, adaptive responses that achieve this imperative "symbiosis." We propose a solution for man's ability to bridge the knowledge gap and evolve as effective consumers of the right information, in the right context, at the right time.

B. "HAN" SCENARIO: CIVIL

1. Business and Home Applications – Present

John wakes up 15 minutes before his preset alarm, concentrating on the events of the day before him. His morning routine remains the same as it has for as long as he can remember. In the kitchen, John opens the refrigerator door and observes an almost empty orange juice container. He extracts a 3x5 note card from his shirt pocket and rewrites the shopping list from a nearby, wall-mounted dry erase board, remembering to add orange juice to the list. John's vehicle is still in the shop for repairs, so he drives his wife's car into work. Upon entering her car, John adjusts the seat, steering wheel, pedals and mirrors before backing out of the driveway. He turns off the stereo due to lack of interest in the present "talk" program and doesn't take the time to search for another station. John spends additional time entering the address to the location of his business meeting into the windshield-mounted GPS. Ten minutes later, mired in traffic, he scans through a myriad of radio stations to distract himself from the stress of being late. John's cell phone rings. His assistant informs him of alterations made to his presentation for today's meeting. She lets him know that the handouts have been forwarded to a printing shop for processing. The location of this business is conveniently situated between John's house and the meeting. John manually programs a waypoint into the GPS re-directing him to the print shop. Minutes later, he arrives to discover that the print shop did not receive the electronic file. He contacts his assistant and has her re-send the [updated] file.

Back at home, John Jr. just removed the last soda from the fridge. After a slight delay at the print shop, John continues to his meeting and delivers a decent presentation despite last-minute changes and an unplanned tardiness. John departs the meeting to run a few errands before a rendezvous with his wife, Jane, to retrieve his car from the service center. He haphazardly enters additional waypoint destinations into the navigation system, intending to accomplish as much as he can before Jane is ready to accompany him. John arrives at the grocery store and is befuddled by the layout. Consequently, shopping takes twice as long as it would have at his familiar neighborhood grocery store. John picks up Jane who is visibly frustrated from waiting beyond their agreed meeting time. Fortunately, they pick up a fully repaired vehicle without fanfare. As they arrive at home, John Jr. eagerly greets his parents with, "Did you guys get any more soda?" Just then, John's cell phone alerts him with a new voicemail.

2. Business and Home Applications – Future

John wakes up well rested with a vague idea of what the day has in store for him. He checks his personal device for an optimized schedule, gets dressed, and places the device into his pocket before proceeding with his morning routine. Once downstairs, John opens the refrigerator door and observes an almost empty orange juice container. Through **touch**ing the door handle, an updated grocery list automatically transfers from the refrigerator to his device; after all, today is grocery day. John's usual vehicle is in the shop for repairs, so he drives his wife's car into work. Through the **touch** of a button on the vehicle entry device, Jane's car authenticates John and automatically adjusts the steering wheel, seat, pedals and mirrors. Simultaneously, John's favorite radio stations emerge as presets, and his last five destinations populate candidate routes into the navigation console. He selects an alternate destination, as he is attending a business meeting at a new location. As he proceeds along the recommended route, the multi-mode interface, currently presenting digital map graphics, also prompts him of a route alteration via **tactile vibrations** in the steering wheel followed by a verbal announcement. John's device received a traffic "congestion" alert along the primary route then automatically calculated and selected a faster one. Further along the commute, John's device receives an updated version of a presentation that John will deliver during his meeting. This communication is received via a MAN to the vehicle and transferred from the steering wheel to John's device. The textual message which accompanied that communication transaction is then transferred from his device through the steering wheel and played over the vehicle sound system. The message, from John's assistant, informs him to print copies of the new presentation before his meeting. Simultaneous to playing this audio alert, the new task is tagged, prioritized and dropped into a dynamically updated list just before "meeting." The device interprets the order and automatically reprograms the route with a waypoint to the closest printing shop; it also attempts to send the updated presentation to this print shop via the MAN. When John arrives, he discovers that, for some reason, the print shop did not receive the electronic copy.

Fortunately, his device retained a copy of the file, and through **touch**ing an interface screen/counter at the print-shop, John uploads the presentation while simultaneously directing the bill to his corporate account. This final act is transparent to John and front-end print-shop assistants, but electronic receipts are stored on his device and in the printing business accounting database.

Back at home, John Jr. just removed the last soda from the fridge. The refrigerator attempts to send an updated shopping list to John's device. After the completion of a successful presentation, John departs the conference to run a few errands before heading home. His device automatically prioritizes the list based on John's preferences, history and the current time, and then optimizes the order, based on his current location and projected destination. John's updated "to-do" list reads: 1) pick up dry cleaning, 2) pick up Jane, 3) retrieve car, 4) buy groceries, and 5) grab take-out. The device calculates an optimum route to intersect all of the waypoints, and coordinates with Jane's device for a suitable pick up time. When John arrives at the grocery store, his purchases are paid for and waiting near the front. Through **touch**ing the check-out stand, John's device authenticates him to the check-out kiosk. Electronic receipts are stored. If the store did not provide this expedited service, John's device remained flexible with an up-to-date shopping list and a charted location of all his groceries for that particular store.

C. OVERVIEW OF EXISTING NETWORKS

In the context of scenarios presented in this thesis, several noteworthy observations emerge when comparing the future with the present. First, the future environment is not significantly different. Hassles and miscommunications persist in person to person exchanges, person to machine interactions, and inter-machine transactions. The difference between status quo and tomorrow lies not in the frequency or type of these miscommunications, but rather, in how we collectively deal with them. Decisions on tedious tasks still require knowledge, albeit routine, and the demand on our [limited] resources remains, if not increases. Automating the Efficient Thought process through HAN components capable of fusing knowledge into relevant, digestible chunks for human decision makers, all but eliminates our conscious interaction with the seemingly mundane. Notice also that current technologies remain quite relevant in the future. Before engaging in a discussion surrounding the emerging technologies capable of delivering this reality, it is prudent to explore the characteristics, proven capabilities, and apparent limitations of established network architectures. A helpful method to categorize the different types of computer network designs is by scale as depicted in Figure 4. We start our discussion, not necessarily with the furthest reaching or largest data communication system, but with the most popular system upon which all others build, the Local Area Network.

1. Local Area Networks (LAN)

LANs allow independent devices such as personal computers (PC) and printers to communicate directly with each other over a common physical medium. The basic LAN concept includes “the real-time interconnection of end-user devices in a local environment for the purpose of sharing information, files, software, and hardware peripheral devices” (Cummins and Keen 1994, 316). In principle, the LAN concept ranges from PCs linked together to share software, common databases, and printers at one end of the spectrum, to the interconnection of telephones within an office building through a PBX at the other. LANs can span a single building or scale across a university campus, the majority of which are usually within 500 meters of each other, depending on the type of cable used for the medium (Cole 2002, 321).

LAN technology emerged from the need for high-capacity telecommunications facilities to enable PCs to share information. In the late 1980s, LANs quickly became the driver of business innovations in the use of PCs. In terms of raw transmission capability and cost effectiveness, LANs rapidly outpaced other networking architectures by providing low-cost transmissions without the usage charges associated with other network topologies. Employing digital technology, LANs matched high-speed digital transmission to high-performance digital computers, further validating their growth (Cummins and Keen 1994, 82-83).

The modern LAN's rising development is also attributable to three casual factors: (1) the abundance of powerful and inexpensive PCs; (2) the lack of responsiveness of management information systems (MIS) departments in meeting applications needs of company work groups; and (3) the need to share software, files, and hardware peripheral devices among the work-group members. LAN technologies are inexpensive, widely available, and they adhere to the fundamental principle of computer networking known as "locality of reference." This principle states that communication among a set of computers is not random, but instead follows two patterns:

> First, if a pair of computers communicates once, the pair is likely to communicate again in the near future and then periodically. This pattern is known as temporal locality of reference to imply a relationship over time. Second, a computer tends to communicate most often with other computers that are nearby, also referred to as physical locality of reference to emphasize geographic relationship. The locality of reference principle is intuitive because it applies to human communication as well
>
> (Comer 2001, 103).

LAN transmission occurs in digital form with the entire capacity of the medium allocated to each signal on the network. Therefore, the potential for congestion and interference among separate transmission signals vying for the same shared medium capacity exists. To avoid this, LANs employ high transmission speeds and methods for managing access to shared media. In the Ethernet (IEEE 802.3) specification, a contention protocol system called Carrier Sense Multiple Access with Collision Detection (CSMA/CD) performs such management. This system relies on each network node to "listen" to the network to determine whether the bandwidth is available or currently occupied with a transmission. If available, the terminal transmits the message and controls the medium until the message is complete. CSMA/CD facilitates efficient use of the network's maximum capacity by listening before transmitting, detecting collisions, and retransmitting, if necessary (Comer 2001, 109).

The most prevalent type of LAN technology in use today is the base band LAN, which consists of computer workstations connected directly to a shared transmission medium (twisted pair, copper wire, coaxial cable, or fiber-optic) configured in either a star, bus, or ring topology (see Figure 8). Generally, one workstation functions as a dedicated server and acts as the repository for network file storage, application software, and the network operating system; however, single LANs may have more than one server attached.

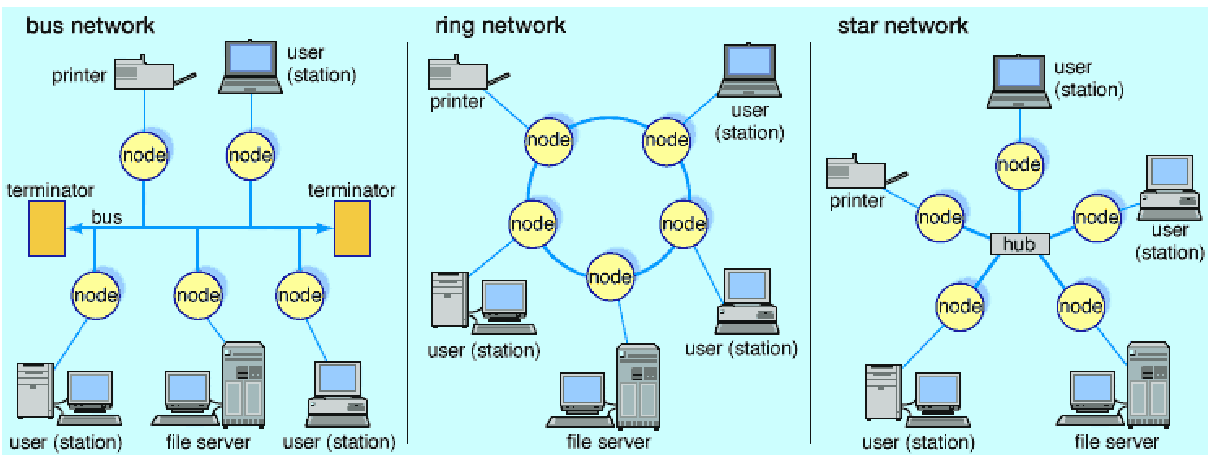

Figure 8. Bus Topology (From Encyclopedia Britannica Online)

The most typical aspects of telecommunications mainly relate to LANs in terms of innovations and standards, as well as problems. The need to link LANs across different types of technology and greater distances gave rise to a new generation of technology that provides interoperability between local and wide area facilities. Wide Area Networks answered the call to expand the network envelope.

2. WAN

Traditionally, a network connecting two or more LANs is called a WAN. While generally slower and more expensive, WANs serve the critical function of spanning sites in multiple cities, countries or continents. They provide connectivity between numerous, geographically dispersed campuses which thesis students require to complete their research on time. Information Technology Professors Peter Keen and Michael Cummins describe WANs as:

> Private or semiprivate networks whose reach extends beyond a metropolitan area. WANs can be regional, national, or international in scope and may either carry only one type of information or be designed for the integrated transmission of voice, data, and video information. A WAN may be restricted to one technology or medium, such as a satellite network or a fiber—optic cable network, or it may utilize a mix of technologies and media configured in a star, mesh, hierarchical or hybrid technology
>
> (Cummins and Keen 1994, 323).

Figure 9 graphically depicts the relationship between LANs and WANs.

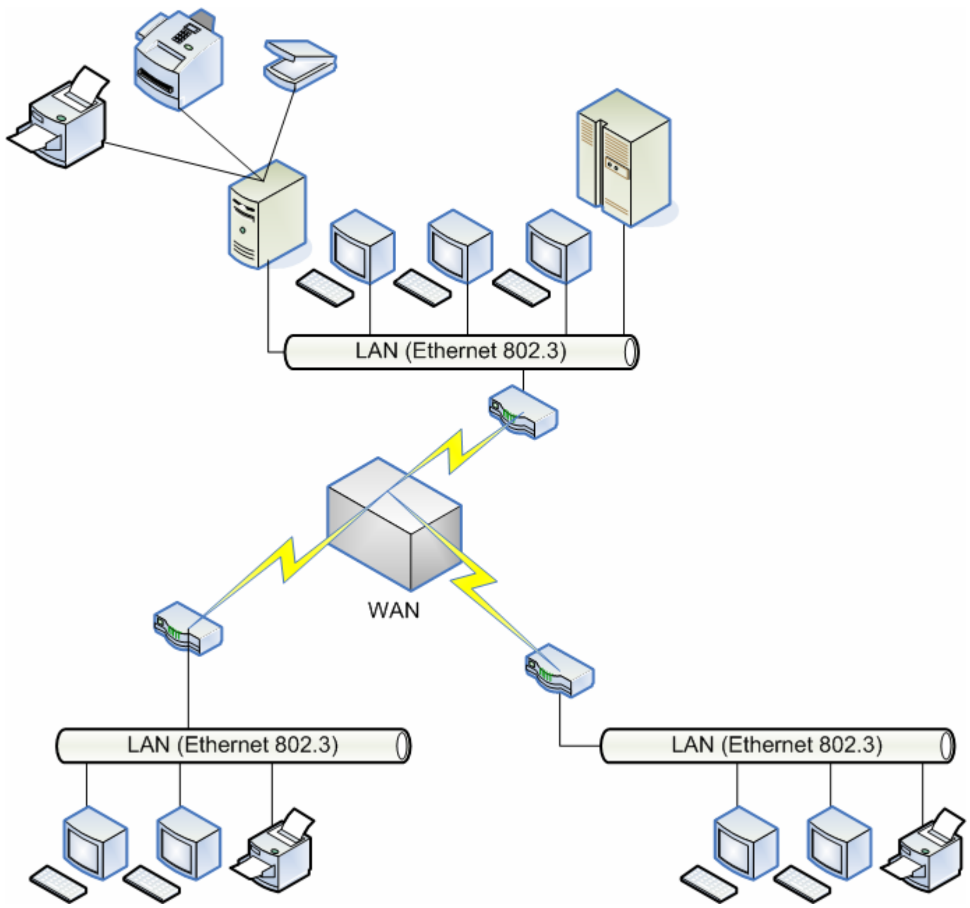

Figure 9. Relationship between LAN and WAN

Today, more businesses operate on-line with increasingly sophisticated applications requiring greater range and rapid responsiveness in order to make money. These trends, combined with the overwhelming economic incentive, fueled the importance and capability of WANs as a telecommunications platform. The WAN movement evolved from completely private networks composed of dedicated circuits and central office switching capacity leased from local and long distance carriers, toward higher-capacity, digital backbone links that interconnect LAN sub-networks while providing long-haul carriage of integrated voice, data, and video information streams (Cummins and Keen 1994, 323).

The key issue that separates WAN technologies from those of a LAN is scalability. A WAN must be able to grow as needed to continue connecting additional sites spread across large distances, with many computers at each site. A WAN should also possess the capability to connect computers of large corporations with offices and factories at dozens of locations spread across thousands of square miles. This is especially evident when one considers the wave of outsourcing in business today. Further, in order for the technology to be classified a WAN, it must deliver reasonable performance for larger networks. A WAN does not merely connect numerous computers at many sites; "it must provide sufficient capacity to permit the computers to communicate simultaneously" (Comer 2001, 198).

A WAN is constructed from many switches rather than point to point leased data circuits that connect one computer to another. Determining the initial size of a WAN is based on the number of sites and the number of computers connected to it. In keeping with the scalability attribute, network designers add switches as needed to connect follow-on sites as well as their respective computers. Almost every form of point-to-point communication has been used to build WANs, including leased data circuits, optical fibers, microwaves, and satellite channels. By design, WANs allow the customer to choose the interconnection scheme.

Unlike a shared LAN which allows only one pair of customers to exchange frames at a given time, WANs permit many computers to send packets simultaneously. A fundamental paradigm of Wide Area packet switching systems is “store and forward switching” in which packets arriving at a switch are placed in a queue until the switch can forward them on toward their destination. This type of system moves packets through the network as fast as its hardware capacity allows. Also, if multiple packets must be sent to the same output device, the packet switch can hold packets in memory until the output device is ready.

Aside from capability and reach, a significant difference between LANs and WANs exists in the set-up costs with the latter carrying heavier price tags. An intermediate solution, enabling the expansion of LANs but not necessarily demanding the global coverage afforded by WANs, gave rise to an intermediate system, the Metropolitan Area Network.

3. Metropolitan Area Network (MAN)

Metropolitan Area Networks serve as data networks for towns or cities by interconnecting users with computer resources in geographic regions larger than LAN coverage but smaller than those areas covered by WANs. MANs merge the interconnection of existing city networks into a single, optimized network that typically spans 50-60 miles with high-speed connections. This interconnection may include bringing together several LANs through a fiber optical backbone, or other digital media, while offering efficient connections to larger WANs. Network managers often refer to the “bridging” of LANs as a Campus Area Network (CAN), which bears similar properties to a MAN, in academic settings.

Recently, service providers began offering the installation of wireless MANs thus diversifying standard interconnectivity models. The emerging Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard, commonly known as Worldwide Interoperability for Microwave Access (WiMax), promises “to deliver ‘last mile’ wireless broadband internet access capable of carrying data intensive applications, such as VoIP and streaming video, to MANs, as well as sub-urban and rural communities” (Ezine). In this sense, some consider WiMax to be a disruptive technology, or an economical alternative to the fixed line Digital Subscriber Line (DSL) and coaxial technologies supporting MANs. The IEEE 802.16e revision, sometimes referred to as Mobile Wireless MAN, extends the MAN envelope to incorporate cell phone networks as well. This modification adds mobility to a wireless technology that remained fixed under previous WiMax standards. Aside from mobile access, WiMax also supports the ‘disruptive’ technology notion by inexpensively extending the MAN to an underserved customer base as indicated in the following quote:

> WiMax will operate over licensed and non licensed frequencies using non line of sight (NLOS) and line of sight technologies, extending broadband coverage to cities and towns wirelessly via a metro area network. Additionally, because of its far reaching capabilities and ease of implementation, WiMax is the one technology likely to bridge the Digital Divide, connecting underdeveloped regions and sparsely populated rural areas much more cost effectively than deploying a wire line infrastructure
>
> (Ezine).

Cisco Systems, Inc. announced their intention to assist in the construction of this “Digital Divide” bridge as early as the summer of 2004. Their Metropolitan Mobile Network solution intends to provide broadband wireless access across cities to public sector agencies including city, state and federal agencies, public safety, transportation, and public works. “With a unified, cost effective IP network foundation, the Cisco Metropolitan Mobile Network addresses the demand of public sector agencies for real-time, mobile access to key applications and tools that may ultimately lead to the increased productivity and responsiveness of city personnel” (Cisco). The end-to-end solution is scalable, like MANs, secure, and standards-based, consisting of routers and interface cards that support wireless LAN and WAN access. Cisco’s proposal also provides the flexibility to deliver applications across the wired and wireless infrastructure which opens the door for improved communications and responsiveness through existing and future wireless technologies. “By providing a flexible architecture to support existing wireless technologies such as IEEE 802.11a/b/g, cellular, satellite and future wireless technologies, customers can take advantage of industry standards for higher performance and more robust security" (Cisco).

4. Wireless Local Area Network (WLAN)

WiMax, as described in the above section, connects computers using microwave radio technology in place of traditional wired connections like DSL, cable or fiber to establish links from 3 miles (NLOS) to 30 miles away (LOS). In contrast, WLANs provide network connectivity between devices within an office space or residence location. In this sense, WiMax is considered an external use system while WLANs are primarily designed for internal use. The main advantage of WiMax and WLANs is freedom from physical wire/copper or fiber to connect to the client. Modems are replaced with antennas, creating more flexible opportunities in military and business arenas. With a background of the larger network systems (LAN, WAN, MAN and WiMax), we shift our attention towards these "internal" networking envelopes, starting with WLANs.

The IEEE 802.11, or WiFi standard, denotes a complete set of standards for WLANs. Originally released in 1997, IEEE 802.11 defined a common media access control (MAC) layer that supported the operation of all 802.11-based WLANs by performing core functions including managing communications between radio network interface cards and access points (AP). Amendments to the standard subsequently defined specific physical layers such as 802.11b, 802.11g, and 802.11a, each employing its own modulation scheme. The three physical layers and their respective data transmission techniques are discussed below.

a. 802.11b

The most popular and widely implemented 802.11 standard operates in the 2.4 GHz Industrial, Scientific, and Medical (ISM) unlicensed frequency band and uses Direct-Sequence Spread Spectrum (DSSS) modulation techniques to maximize the use of limited channels across the 2.4 GHz spectrum (11 in the U.S., 13 in Europe, 14 in Japan) (Procurve). The channels overlap with a 5 MHz separation between the centers of adjacent channels leaving only three channels in the 2.4 GHz band as non-overlapping. This means that devices within range of one another will potentially interfere with each other's operation. Additionally, manufacturers of other devices can use the 'unlicensed' 2.4 GHz ISM band to produce a plethora of everyday products including: microwaves, cordless phones, Bluetooth devices, wireless headsets, garage door openers, etc. The maximum data rate for 802.11b tops out at 11 Mbps with realistic maximum useable throughput around 4-6 Mbps under normal conditions. This is due to the management and processing of protocol overhead and control frames which must transmit at the lowest supported data rate.

b. 802.11g

Extending the capabilities of 802.11b, this standard increases the maximum data rate to 54 Mbps thereby serving up to five times as many users. The increased data rate can be attributed to a more efficient means of transmission called Orthogonal Frequency-Division Multiplexing (OFDM). "OFDM breaks a wide-frequency channel into several sub-channels and transmits the data in parallel" (Procurve). The realistic maximum useable throughput is about 20 Mbps which remains five times proportionally higher than its predecessor. 802.11g can also scale back to support data rates at 48, 36, 24, 18, 12, and 9 Mbps, if necessary. Another benefit of sharing the same spectrum as 802.11b is the backward-compatibility between 802.11g and 802.11b devices. One should exercise caution, however, when employing 802.11b and 802.11g stations within range of one another. A Request to Send/Clear to Send (RTS/CTS) message can deconflict simultaneous transmissions between the different devices and avoid collisions and [timely] retransmissions.

c. 802.11a

This standard delivers the same 54 Mbps data rate as 802.11g but avoids an overcrowded spectrum wrought with interfering devices by operating in the higher 5 GHz ISM band. The 5 GHz band allocates up to 19 non-overlapping channels thereby enabling the placement of more APs within a given area. This makes 802.11a ideal for providing connectivity to densely populated user environments such as airports, malls, or classrooms. The tradeoff of higher frequencies, however, is limited range. Additionally, shorter wavelength signals do not penetrate walls and other obstructions as easily as the 2.4 GHz spectrum. A final consideration for implementing 802.11a standards is the lack of backward compatibility with 802.11b and 802.11g equipment.

Regardless of the standard employed, WLANs must ensure that they share the transmission media correctly. A contention protocol system known as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is used to manage this effort. Rather than depend on networked computers to receive all transmissions as they do with CSMA/CD in LANs, WLAN collision avoidance triggers a brief transmission from the intended receiver before transmitting a packet. These control messages are much shorter than data frames, significantly reducing the probability of second collisions.

5. PAN

WLANs created countless opportunities for individuals to mobilize themselves while maintaining continuity of computer operations through [somewhat] seamless connections. Proximate to this trend, the industry of personal electronic devices developed smaller, lower-power, less expensive appliances supporting personal information applications and communications. Cellular phones, pagers, PDAs, GPS, pocket video games and several other devices, all delivering their own set of capabilities, promptly found their places on our belts or comfortably inside of our pockets. In retrospect, a person in possession of these many components, however, carried five displays, three keypads, two sets of speakers and microphones and three communication devices (Zimmerman 1995). This hyper-redundancy, though seemingly necessary at the time, resulted from the devices' inability to exchange data with each other. In essence, they operated independently, without an intermediate network around the body. Connecting the devices would not only enable the sharing of input/output functionality, storage and computational resources, it would increase the usefulness of those remaining personal information devices (Ibid). The concept of PANs was thus born out of perceived necessity, much like preceding network architectures.

PANs allow communications among computer devices close to one person, but not necessarily belonging to that individual. The envelope of a PAN typically spans from a few meters to no more than ten meters. This distance provides sufficient range for the intrapersonal communication of multiple, personal devices. It also permits connections to higher level networks (WLAN or WiMax, as described above). PANs can be wired via USB or FireWire but more commonly achieve networking wirelessly through Infrared Data Association (IrDA), Bluetooth, or Ultra-Wideband (UWB). These are sometimes referred to as Wireless PANs (WPAN).

WPAN technology remains a rapidly developing field with operating frequencies around 2.4 GHz (for digital modes). Recall this is the same frequency as our sprawling 802.11b/g WLANs and several other appliances that share this crowded, unlicensed portion of the electromagnetic spectrum. The objective of PANs is to facilitate seamless operation among personal devices and systems thus enabling every device in a WPAN to plug in to any other device in the same WPAN, provided they are within range of one another. A loftier goal proposes the worldwide interconnection of WPANs.

The Personal Area Network (PAN) concept originated in the mid-1990s with the Physics and Media Group at the Massachusetts Institute of Technology (MIT) Media Laboratory. Initially an experiment investigating the interconnection of body-borne information appliances and electric field sensing to position measurement, Professor Gershenfeld and, then student, Thomas Zimmerman, realized that by modulating the electric field used for position measurement, data could be transmitted through the body. This accidental, yet monumental discovery paved the way for the most intimate circle of networking to date: the Human Area Network.

Zimmerman's research proposed PANs as a means to bring functionality closer to humans through the integration of previously disconnected components. Manifestations of PANs attempting to deliver this promise include Bluetooth, Zigbee, and IR link, to name a few. As these and similar technologies flood the marketplace, carrying PAN and HAN labels, distinguishing what components belong to which network architecture becomes a challenge. The accurate qualification, by name, capability, or implementation remains critical, however, due to potential variance in protocols and subsequent interoperability between components, the latter of which served as a pillar to Zimmerman's original vision.

Fundamental differences exist between implementations of PANs today and the PAN envisioned by Zimmerman over a decade ago. While PAN technologies, including those previously mentioned, effectively network personal devices, they communicate in a manner that abandons Zimmerman's research on near-field capacitance. Reverting to known Radio Frequency (RF) standards in the 2.4 GHz spectrum, Bluetooth (IEEE 802.15) seized the market from its inception in 1999 through 2005 where an estimated 700 million devices were in use (Hayes-Roth 2003*,* 273). This successful initiative quickly became the de facto standard for PANs, leaving developmental room for vendors to disrupt the seemingly ubiquitous technology with a new networking paradigm.

6. HAN

RedTacton, a Japanese telecommunications company, recently coined the term HAN in categorizing applications based more closely on Zimmerman's original research. In this sense, HANs distinguish themselves from other network models through their direct, deliberate integration with the human user. They exchange information through interfaces connected to the human body, or some attribute of the body, i.e., finger, hand, foot, etc. While aspects of HANs existed in early computing, burgeoning capabilities are tightening the gap between networks and humans. Imagine a network diagram illustrating the minds of human users at the hub of networks, rather than computers or routers. HAN technologies are pushing that prospect away from the science fiction domain and into the realm of tomorrow's reality. The fact that entire networks, consisting of components, machines, and data, center on the prompt delivery of relevant knowledge to the human mind, merely reinforces this evolutionary migration. With HANs, knowledge transactions will become a rapid, intuitive, secure means of reliable communications.

a. Difference between PAN and HAN

The primary difference between PANs and HANs remains the human's significance in the latter. With PANs, short of button-pushing and configuration, the human's role is relatively passive. Generally speaking, PANs facilitate autonomous communication between electronic devices, though sometimes without the explicit permission of users. Other differences correlate to research conducted by anthropologist Edward T. Hall, who postulated measurable regions of interaction around people (Figure 10). Hall's findings reinforce the notion that distance affects the manner in which humans interact with each other (Hall 1966, 114). This begs the question of whether or not similar patterns exist between people and their electronic devices, i.e., behavior changes based on the proximity of various technologies. The evolution of networking currently resides in a phase where the proximity of the network exists near the user's "personal ring." Aside from controlled, experimental exceptions, the network has yet to transcend the final, "intimate" boundary, the same region in which Zimmerman focused his original research.

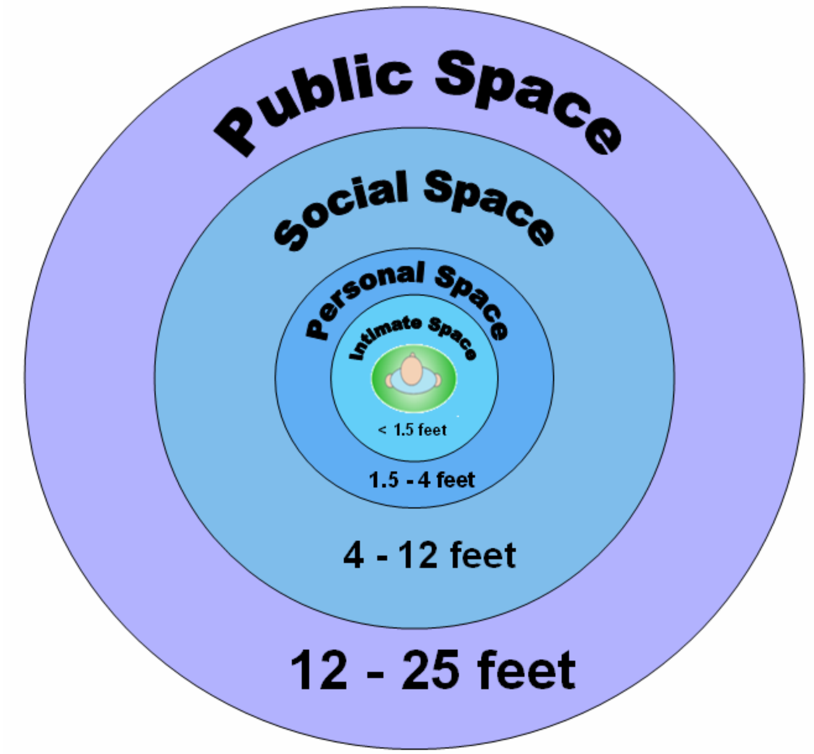

Figure 10. Rings of Personal Interaction (After Hall *The Hidden Dimension*).

Another criterion for qualifying HANs excludes any technology relying on the electromagnetic spectrum for its transmission(s). This logic suggests that remaining communications technologies which fundamentally rely on humans for functionality qualify as HAN candidates. The following example illustrates the difference between PAN and HAN: Apple's iPhone establishes Bluetooth (802.15) links in support of wireless earpieces (Apple). This functionality represents PAN, not HAN. Headphones, as a means of communicating MP3 data from the iPhone to the human ear without fiddly wires or interference from other wireless devices, feed audio signals through the listener's body via a capacitor carrying tiny electrostatic charges from the iPhone to a pair of conductive ear pads in the headphones themselves (New Scientist Tech). While these technologies have yet to be "paired", their coexistence exemplifies HAN, not PAN.

Table 1 provides a summary of the various network designs from the furthest reaching WAN to the closest, more personal HAN.

Network Designs	Description
Wide Area Network (WAN)	-WANs connect two or more LANs spanning sites in multiple cities, countries or continents; WANs employ microwave, radio wave, coaxial cable and fiber optic
Metropolitan Area Network (MAN)	-MANs interconnect users with computer resources in geographic regions larger than LANs but smaller than WANs; primarily intended as data networks for towns or cities
Local Area Network (LAN)	-LANs connect computers in single buildings or across university campuses for the purpose of real-time sharing of information, files, software, and hardware peripheral devices
Wireless LAN (WLAN)	-WLANs connect computers within an office space or resident location using microwave radio technology in place of traditional wired connections like DSL, cable or fiber to establish links
Personal Area Network (PAN)	-PANs facilitate autonomous communication between electronic devices close to one person but not necessarily belonging to that individual; PANs span 3-10m and allow intrapersonal communication of multiple devices
Human Area Network (HAN)	-Wireless communication system that allows electronic devices on/near the human body to exchange digital information through interfaces permitting near-field electrostatic coupling; HANs distinguish themselves through their direct, deliberate integration with human users

Table 1. Summary of Network Designs by Scale

D. TAXONOMY OF HUMAN AREA NETWORK IMPLEMENTATIONS

Figure 11 describes the potential world of HANs. Fundamentally, the diagram reveals lines of distinction which differentiate HANs from other network architectures, thereby establishing a HAN taxonomy. Examination of the diagram exposes four branches radiating from the HAN trunk. Each branch represents a root aspect of HAN and establishes its own unique stems. This division continues to termination at a leaf, which represents an application of that aspect of HAN. The “Human Role” branch describes the function of the individual in the network. Information travels through, or to them. In the latter case, the person acts as the source, destination, or both as the technology dictates, equating to leaves on the "Human Role" branch. The clarity of the "Sense" branch rings clear; however, on the more obscure "Direction" branch, leaves indicate the direction of information transfer through, from, or to the user. The somewhat obscure "Interface" branch expresses different methods of integrating information with the user. A kinetic interface, for example, might provide inputs to the user through vibration (the rapid oscillating movement of a mechanical component), or the interface might sense movement from the user, interpret the information, and apply it toward some user defined end-state. Chemical interfaces reach further into unfamiliar territory, however, not beyond the proximation of this diagram. Imagine a device that could sense a person's hydration level based on the chemical composition of his perspiration, or, conversely, the interface might provide chemical feedback to the user's olfactory system. Ultimately, the diagram strives to provide a means of describing present and future HAN manifestations while excluding imposters.

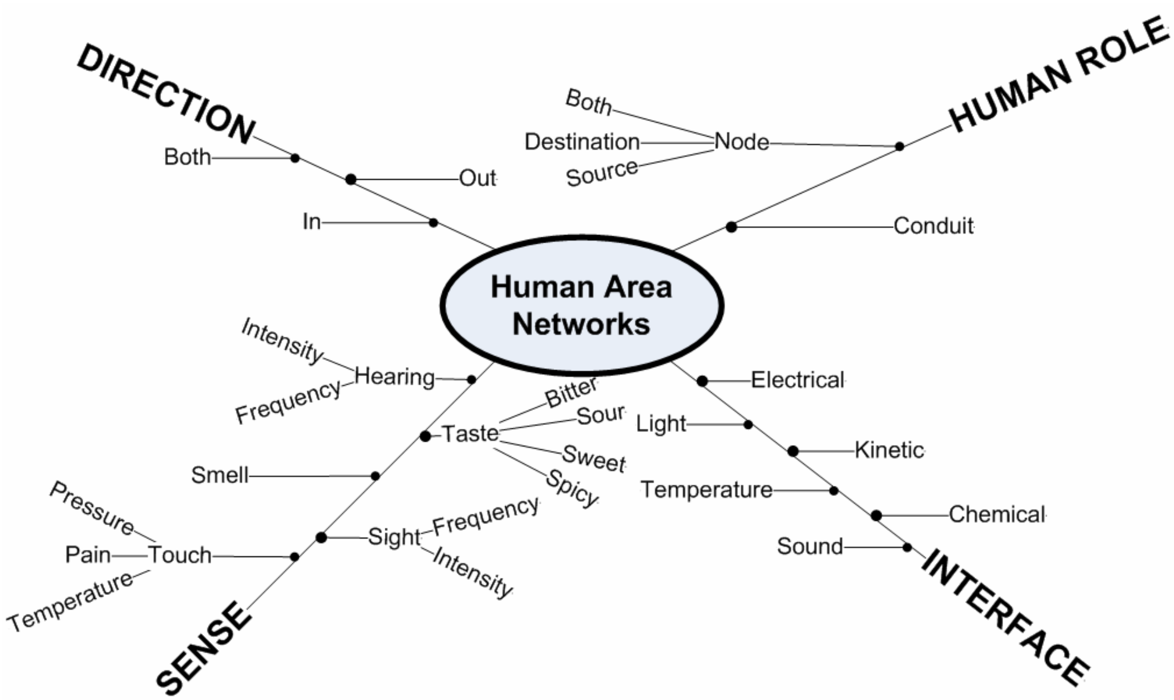

Figure 11. Proposed HAN Taxonomy

Developing the HAN taxonomy led to the following significant discovery: devices previously not recognized as [new] HAN components retain relevant positions in this model. It seems counterintuitive to include relatively "old" interface components such as headphones, monitors, and keyboards with cutting edge technology, but these familiar tools remain functional, applicable HAN devices. Further consideration led to the conclusion that most of these former exceptions occurred where the "Human Role" served as a node. Ultimately, these devices are classified as Human-Computer Interfaces (HCI), Human-Machine Interfaces (HMI), or Man-Machine Interfaces (MMI); all of which are synonymous. Subsequent discussion will therefore not belabor established concepts and technologies, except where they contribute novel steps toward the future.

E. CURRENT IMPLEMENTATIONS OF HAN

Despite limited appearances in the marketplace, numerous published works exist pertaining to the concept of Human Area Networks. This section groups and summarizes several experimental implementations on the verge of tilting current market trends.

1. Tactical Situation Awareness System (TSAS): Aviation Variant

The U.S. Navy designed TSAS as a lightweight vest fitted with tactile stimulators, called "tactors" which, through a sensor-control system, deliver various alerts in the form of tactile information to the wearer (Wernecke 2003). Initial field testing focused on augmenting human sensation and perception by providing continuous, intuitive information regarding spatial orientation for pilots of vertical lift aircraft. The military anticipates that this system will reduce workload and increase flight safety by eliminating the need to constantly scan instruments during periods of limited visibility or obscuration of ground references for all phases of flight, with special emphasis on the landing phase. TSAS provides hover, climb, dive, steering, and threat warning cues to the pilot. In a sense, the system functions as an extension of existing instruments, and augments the visual stimuli provided by those instruments through "touch."

Initial testing of TSAS saw tremendous success with positive feedback from all test pilots. Subjective performance evaluations provided unanimous evidence which indicated the vest's effectiveness at reducing [human] workload and its ability to improve situational awareness. Additionally, pilots found the vest comfortable and conducive to performing other routine operations inside the aircraft. This last bit of feedback bears particular significance, with respect to the degree of user satisfaction, due to the stigma service members hold towards 'additional equipment' (Griffin 2001).

2. Tangible Bits

Professor Hiroshi Ishii founded the Tangible Media Group at the MIT Media Lab in order to pursue the vision of "Tangible Bits" near the end of 1995. This concept allows users to "grasp & manipulate" bits in the center of users' attention by coupling these bits with everyday physical objects and architectural surfaces (Ishii 1997).

> Tangible Bits, our vision of Human Computer Interaction (HCI), seeks to realize seamless interfaces between humans, digital information, and the physical environment by giving physical form to digital information and computation, making bits directly manipulable and perceptible. The goal is to blur the boundary between our bodies and cyberspace and to turn the architectural space into an interface
>
> (MIT Media Lab).

Tangible Bits also enables the user's awareness of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. In some capacity, Tangible Bits function as input devices; in other cases, they behave as output devices.

The above abstract characterizes Tangible Bits as a HAN technology based on its penchants towards the human interface. This concept also mirrors the proposed HAN taxonomy, especially in its interaction with the user along the sense and interface spines.

3. Touch Trackball and Mouse

In 1999, Microsoft presented a streamlined variation of two, traditional HAN devices. Since most computer input devices could not previously detect when users touched or released them, the technology corporation integrated touch sensors onto trackball and mouse devices, dubbing them Touch Trackball and Touch Mouse. The simple modification enabled these devices to empower computers with more information than cursor movement and button clicking. Consider word processing programs, for example. When entering text using the keyboard, users have little to no use for toolbars. Applications enabled for use with the Trackball/Touch Mouse fade out unnecessary toolbars while users employ the keyboard, making more efficient use of coveted monitor “real estate”. Once the user touches his or her mouse, indicating intent to employ a pointing device, the toolbars and menu structure reappear. Similarly, touching the Trackball transforms displays into reading-friendly presentations in an effort to match the user’s expectations for using that feature (Hinckley 1997).

The Touch Trackball and Touch Mouse are fundamentally simple improvements that do not provide expanded capabilities for computers. Instead, they significantly enhance the user’s experience by anticipating his or her intent through touch, and delivering responses congruent with those expectations. Achieving this improved perception requires enabling the computer with one additional piece of information, touch, and the subsequent ability to automatically translate that event into predictable action.

4. Health Monitoring

In the late 1980’s, Johns Hopkins University collaborated with NASA’s Goddard Space Flight Center to develop core body temperature sensor technology. CorTemp™, dubbed the "thermometer pill", was designed to monitor the internal core body temperature of astronauts to measure and relay human conditions during space flight (HQ Inc.). The silicone-coated capsule contains a micro battery and quartz crystal temperature sensor that "vibrates at a frequency relative to the temperature of the surrounding substance (body), producing a magnetic flux and transmitting the signal harmlessly through the body" (Ibid). A data recorder collects and stores the data in solid-state memory until it can be downloaded onto a computer.

HQ Inc. now manufactures disposable electronic capsules as part of their CorTemp Physiological Monitoring System. Once ingested, the capsule provides 24 to 36 hours of core body temperatures accurate to 0.1˚C by means of a radio interrogator (Jones 2006). A mere one meter transmission range permits the use of many capsules in relative proximity without interference. While athletes and trainers typically use this device for monitoring the core temperature of football players during summer training, another budding market awaits. Extending this technology to the military, where troops routinely face exposure to extreme conditions and life-threatening wounds, might reveal other applications for battlefield medicine and internal health status monitoring.

The radio pill offers yet another perspective on how devices can be used to close the Human-Machine divergence. This capsule senses a person's internal temperature and transmits that data via RF to another device. In this sense, the human serves as a node in the network, namely, the source of the data acquired.

5. Remote Key Chain

Privaris, Inc., a company based in Fairfax, Virginia, developed a device in 2006 that makes biometric identification portable. "PlusID" serves as a fingerprint ID scanner that fits on a key ring with the ability to grant access to myriad other devices such as Radio Frequency Identification (RFID) readers, Bluetooth radios, and potentially controlled access areas like residential homes or classified workspaces (Moore 2006). With some added functionality, PlusID becomes a portable and ubiquitous authentication device which significantly enhances its overall value to the user. Potential military applications in this arena should not be overlooked, especially when the technology becomes integrated into existing, mature appliances such as cellular phones or PDAs.

Privaris introduced a biometrics-based product that emanates HAN. The power of interfacing directly with users from the first step of validating identity empowers computers to a new realm of configurability and portability.

6. Touch Screens

Touch screen displays represent another ever-evolving HAN technology that falls under the aforementioned realm of HCI. Some of the more cutting-edge touch screen technologies like Apple's iPhone and Microsoft's Surface allow for multiple inputs. This enhances the user experience by producing more intuitive and interactive experiences with the interface. A few, noteworthy touch screen implementations follow.

Jun Rekimoto, at Sony Computer Science Laboratory's Interaction Lab, developed a new sensor architecture for making interactive surfaces sensitive to human hand and finger gestures. Rekimoto's research improves the interface's understanding of human action and further evolved the intuitiveness of touch screen interaction (Rekimoto 2002).

Lee, Dietz, and company in a joint effort between Carnegie Mellon University and Mitsubishi Electric Research Laboratories developed a Haptic pen for use with touch screen devices in 2004 (Lee 2004). This pen serves as a simple, low cost device that provides individualized tactile feedback for multiple simultaneous users and the pen is capable of operating on large touch screens as well as ordinary surfaces.

Touch screens naturally emulate HAN technologies. They transform traditional interfaces into intuitive devices by facilitating the human manipulation of machines through the most basic mechanism of interaction: touch. This interaction receives further improvement by modeling the interface after the manner in which humans manipulate the physical world through multi-touch, collaboration, and gesture recognition.

F. NETWORKING BY TOUCH WITH INTRABODY COMMUNICATIONS

The touch-enabled technologies showcased above provide examples of functional HAN implementations, but none aspire to using the human body as the actual means of transmitting and receiving data. The following section returns to the core of Thomas Zimmerman's original research at MIT which includes a method to communicate data using the body as a medium.

1. Origin of Intrabody Communication (IBC)

The fortuitous discovery of transmitting data through the body led Thomas Zimmerman to propose a wireless communication system that would allow electronic devices on and near the human body to exchange digital information through near-field electrostatic coupling. In his 1995 master's thesis, he describes a communications device proximate to the user's body, capable of transmitting information by modulating electric fields and electrostatically coupling Pico amp (pA) currents through the body. This phenomenon is henceforth referred to as Intrabody Communication (IBC). In IBC, the body conducts a tiny current of 50 pA to body mounted receivers and the environment, referred to as "Earth Ground", providing a return path for transmitted signals. Zimmerman used a low frequency carrier, e.g., 330 kilohertz (kHz) which prevented energy propagation and in turn, minimized remote eavesdropping and interference from neighboring devices. He also employed on-off keying with quadrature detection to transfer digital information, reduce stray interference, and increase receiver sensitivity. Finally, he integrated a low cost half-duplex modem using an analog bipolar chopper and integrator as a quadrature detector and a microcontroller for signal acquisition. Zimmerman concluded that the technology used to create this HAN could be integrated into a custom Complementary

Metal–Oxide–Semiconductor (CMOS) chip to achieve the smallest size and lowest cost (Zimmerman 1995). Figure 12 provides a crude demonstration of Zimmerman's original device.

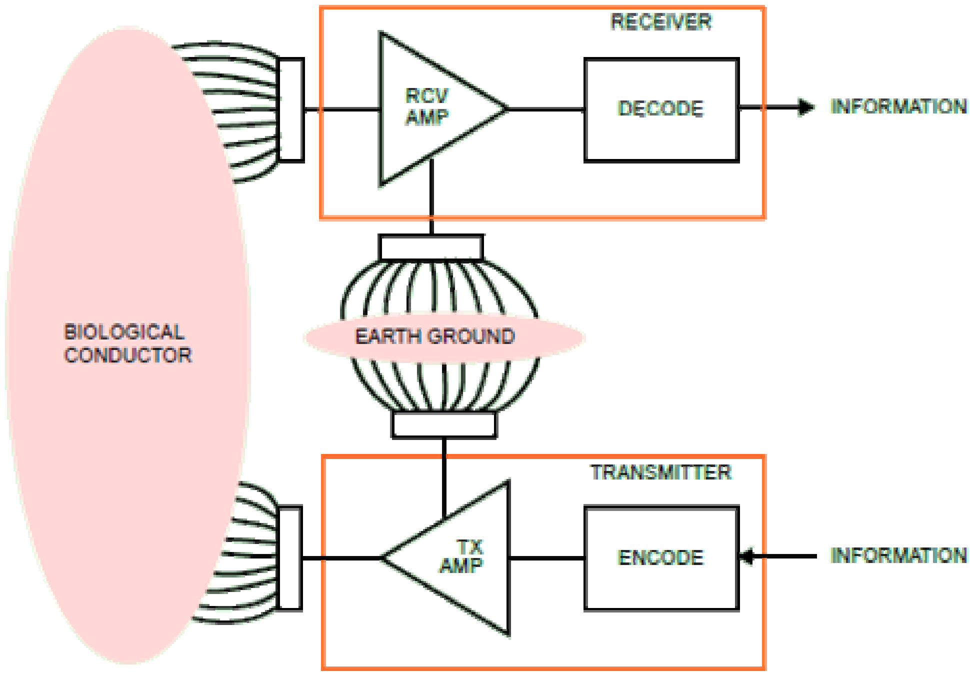

Figure 12. Rudimentary IBC System Diagram (From Zimmerman 1995, Figure 1.)

Zimmerman uncovered several important points with the presentation of this breakthrough discovery, one of which highlights the inherent limitations of IR and RF communications. Another significant finding relates to the security of IBC due to increased signal attenuation. For example, the transmission strength of traditional wireless communications decreases with the square of distance as compared to IBC which decreases with the cube of distance. This makes intercepting data from an IBC device a very personal affair as one must be extremely close to the emanating source.

A careful review of existing literature on the resistivity of human tissue exposes the human body as the perfect conductor. Zimmerman further explores the possibility of modulation schemes that would permit even greater data flow over the body. In his continued quest for efficiency, he identifies limitations of power consumption and bandwidth, and proposes a method of powering an IBC device using routine ambulation. Finally, Zimmerman insinuates that the reason people remain encumbered by numerous personal digital devices directly relates to the inability of these devices to intercommunicate. He then proposes methods by which IBC enabled devices might discover each other and establish communications to create a network (Zimmerman 1995).

2. Refining the Next Generation of IBC Technologies

The impetus of Zimmerman's thesis led other researchers to refine the science of IBC. Researches from the University of Washington defined the effects of different physical configurations of IBC electrodes with respect to signal strength and bandwidth (Partridge 2001). Dr. Kurt Partridge and company intended to promote design guidelines for IBC and identify the best contexts for effective deployment thereof. Their research concluded that electrodes near the end of the lower extremities perform better as a result of the proximity to Earth Ground; however, all configurations maintained sufficient strength for communications. Additionally, they observed that a contact area as small as a few cm^2 is large enough, but this aspect requires further experimentation as the University of Washington scientists experienced high variability in their testing. They also recommend pairing with other tactile-based technologies and implementing a collision-based link-layer protocol to handle coordination of multiple devices (Ibid).

Complementary research by The University of Tokyo's Keisuke Hachisuka and his experimentation team, determined the optimum frequency range for IBC as 2-20 Megahertz (MHz) (Hachisuka 2003). Additionally, they determined the distance between transmit and receive electrodes to be relatively insignificant. Similarly, the composition of the electrode does not significantly affect the functionality of the circuit. Monitoring the quality of communication during active movement of the test subject, Hachisuka determined that physical activity did not degrade the quality of the communications link. He also contends that frequency modulation (FM) should be utilized due to its higher noise resistance as compared to other modulation schemes (Ibid). Finally, Hachisuka concludes, through other experimentation, that one transmit and one receive electrode is the optimal configuration for transferring information through the body capacitively (Hachisuka 2005).

A third team of researchers from Chiba University, Japan published results from experimenting with IBC. They concluded that configuring IBC devices for transmit and receive without ground yields the most optimal composition (Ruiz 2005). This team also discovered that electrodes experience the least amount of noise when the surface area of the individual electrode is approximately 2 cm^2 with the optimal frequency somewhere in the 1 MHz to 600 MHz range (Ibid). Further Chiba University experimentation tested higher frequency communications; as high as 3 Gigahertz (GHz). This led to a refined optimum bandwidth of 200 MHz to 600 MHz. They also successfully applied several multiplexing schemes and deduced that Binary Phase Shift Keying (BPSK) and Minimum Shift Keying (MSK) performed most satisfactorily and maintained suitability over longer ranges (Ibid).

Researchers at Nippon Telephone and Telegraph (NTT) in Japan also published their IBC research. They demonstrated the ability to establish an IBC link that conformed to the IEEE 802.3 standard (Shinagawa 2003). NTT also used electro-optic (EO) sensors to augment the purely electric sensors used in preceding experiments. The use of EO sensors improved the operating range and data throughput from earlier IBC calibrations by eliminating the need for a ground. Two disadvantages of the EO sensor were revealed during experimentation: (1) instability from laser beam reflection and (2) increased power requirements. Fortunately, the advantages imparted by the EO sensor outweighed both of these hindrances (Sasaki 2004).

3. IBC Implementations and Adaptations

When consumer-oriented companies begin to develop, patent, market, and field new technologies, a fledgling technology's level of maturity evolves from that of experimental and theoretical into consumer grade quality. Many potential applications exist for the IBC in different market segments. As of this writing, the aforementioned NTT developed an instantiation of IBC in their RedTacton technology. Presently RedTacton exists only as a prototype; however, NTT is actively pursuing marketable applications. Business opportunities proposed for RedTacton include displacement of current PAN technologies, assisting in the intuitiveness of human-machine interactions, personalizing devices, and increasing security (RedTacton).

The German-based company, Skinplex, markets a similar IBC-driven product. Although the maturity of their product slightly lags that of RedTacton, Skinplex aims at more diverse and robust markets, and could potentially develop a product line. Skinplex's current focus remains developing solutions for security, safety, data collection, ambient intelligence, health care, and automatic environmental customization (Ident Technology).

Korea's Basics Research Lab postulated another similar IBC-based idea. Their Touch-And-Play concept allows users to establish connectivity, transfer data, and select service from a multimedia device by means of touch. While their product presently exists mostly in theory, print, and picture, the potential opportunities for Touch-And-Play applications are limited only by the imagination (Park 2006).

Microsoft patented a method and apparatus for transmitting power and data to devices coupled to the human body. The apparatus uses the human body as a medium over which it distributes data and power to devices. A power source coupled to the human body via a set of electrodes distributes power to devices attached to the body. Devices also electrically coupled to the body receive power from the source. By using multiple power supply signals of differing frequencies, the source can selectively power different devices (Williams 2000).

Researchers at the Mitsubishi Electric Research Lab took multi-touch display technology one step further and implemented a collaborative aspect. Using IBC, the DiamondTouch display identifies independent users, and processes their inputs separately. DiamondTouch accomplishes IBC in a unique fashion by identifying users by the chair they sit in, rather than by a device they carry. Consequently, all required equipment is provided and interaction with the display only requires the user to sit down rather than carry an IBC device capable of identifying himself (Dietz 2001).

Sony filed a patent on wireless headphones that transmit sound information from the device to the headphones through the human body. The headphones utilize a high frequency signal which provides enough bandwidth for a high quality stereo signal (New Scientist Tech).

Fukumoto and Tonomura at NTT Human Interface Laboratories in Japan developed an input device they call the FingeRing. It is a wearable input device that senses typing action on any surface and transmits the information through the body to the appliance (Fukumoto 1997).

RedTacton, Skinplex, and a variety of other, aforementioned companies, made use of available research and established viable applications for IBC, however their work merely laid the foundation for exploiting IBC's potential. As other companies discover more innovative applications, manifestations of IBC-enabled technologies will become ubiquitous. Ultimately, IBC will significantly diminish the rift between users and their information, both literally and figuratively.

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III. PROPOSED SYSTEM CONFIGURATION / ARCHITECURE

A. DEFINING THE ARCHITECTURE

This chapter addresses the second thesis question, "What are the key architectural components of HAN and 'Networking by Touch'?" A precursor for providing an adequate response to this question requires the existence of a developed HAN architecture. Since the current state of HAN technologies remains relatively immature and without this fully-developed prerequisite, the following section proposes a component-based architecture, then addresses how these components integrate to ensure its successful implementation.

1. A Definition for Architecture

Many published articles make significant contributions to the formation of architectural descriptions pertaining to HAN technologies. Unfortunately, these previous efforts conclude without describing how specific component architectures fit into a comprehensive HAN realm in which potentially an infinite number of components can interact with each other opportunistically through the power of touch. This frustrating trend is due, in part, to varying expectations including the purpose architectures serve, what they should contain, and how these contents are assembled and subsequently put to use. Simply defining it proves challenging enough, as the Software Engineering Institute's Web site lists over 60 explanations (Software Engineering Institute). In order to achieve a common understanding, this next section provides insights into what makes up an architecture.

The simplest definition for architecture boils down to a plan for assembling things based on a framework for integrating components. In the realm of information technology, this term abounds due to a desire to fulfill answers for many different questions. Some of these include: how can one [economically] reuse things or how does one improve part of something without starting from scratch? Much like natural selection, architectures foster processes for fixing or changing broken parts while keeping and enhancing remaining components.

This reuse of suitable components reinforces selection and improvement which caters to an evolutionary approach. An architecture that coevolves with ever-changing technology retains its value over time and avoids costly rewrites that end up lagging behind the rate of technology growth.

Architectures tend towards the abstract, leaving out necessary details. After reviewing an architecture, one should expect to identify the essential parts, describe how they 'fit' together, via subsystems and components, and understand why the important qualities are expected in assembled, final products (Hayes-Roth, 24 January). Adhering to these principles ensures the ability to achieve complex results by incorporating more knowledge into existing components which facilitates the assembly of new things. This notion reinforces the concept of reuse and improvement through a natural selection process which subsequently leads to accelerating returns for businesses (Ibid). None of the above benefits can be realized, however, if the initial assumptions are invalid or wrong, which explains why architectures take time to develop.

Scope limitations coupled with an immature technology preclude this work from delivering a finished architecture. Unlike previous attempts, however, this thesis provides a comprehensive framework for successors to systematically develop a more complete HAN architecture. Our model for the development of interoperable HAN technologies is composed of various elements, each of which potentially encompasses its own separate thesis. For the purpose of establishing a foundational framework, this thesis introduces a vision of future HAN implementation, explores the formative stages of functionality in the HAN model, and presents functional and quality attributes, all of which must be fully incorporated into the development of any [new] components.

2. Network Architectures

Technical architectures or, telecommunications strategies, serve as master blueprints of standards for networks. These standards provide the foundation that ensures interoperability of equipment, information, and services to meet specific business needs (Cummins and Keen 1994, 48). Together, architecture and standards comprise one subset of five main building blocks for any telecommunications network, the other four of which are summarized in Table 2.

	Building Blocks	**Examples**
Five Main Building Blocks of a Telecommunications Network	Terminals	Personal computers, telephone, satellite earth stations, cellular phones, computers,
	Transmission Links	Twisted pair copper wire, coaxial cable, ultrahigh frequency (UHF) radio, line-of-sight microwave, fiber optic cables, infrared
	Transmission Protocols	Circuit switching, packet switching, analog, digital
	Nodes and Switches	Bridges, routers, private branch exchange (PBX), multiplexers, gateways, concentrators, front-end processors
	Architecture and Standards	Transmission protocols (Ethernet, Token Ring), message format standards (X.400, X12), network architectures (SNA, OSI), network management standards

Table 2. Building Blocks of Telecommunications Networks (From: Cummins and Keen 1994, p 48)

These network building blocks define interfaces between equipment and applications as well as the procedures for sending and receiving information. In this sense, "interfaces" mark the points of interconnection between two (or more) devices, such as between printers and personal computers (Ibid). In the case of HAN capitalizing on IBC, these interfaces become increasingly critical as they eventually comprise the communications between every device in which the human deliberately contacts through the act of touch. A compatibility solution is therefore necessary to ensure that users' expectations are consistently met through the interconnection of devices and their subsequent integration with the user.

Integration includes the combination of telecommunications, computing, and information management and serves as the central driving force across the information technology field. It requires compatibility, or, the ability of a wide variety of components to operate together. Historically, this conundrum turned out to be extremely challenging, due primarily to differences among various vendor products coupled with the exponential pace of technological change (Cummins and Keen 1994, 77). A pressing need existed for established forums to ensure commonality of standards.

B. STANDARDS AND MODELS

"Standards remain at the heart of the telecommunications field today and define the limits of the practical versus theoretical" (Ibid, 48).

1. Open Systems Interconnection (OSI)

The OSI model offers one of the most focused efforts to conquer compatibility issues. Develop by the International Standards Organization (ISO), "OSI served as a 'reference' model intended to guide the development of products, not to define the product itself" (Ibid, 79). Its purpose remains to establish "complete and consistent communication rules that permit the exchange of information between dissimilar systems" (Ibid). As a reference model, it helps provide a framework for defining several key standards.

The OSI model is referred to as a "layered" architecture approach to communications standards (see Figure 13). Each of its seven layers represents a necessary element in the electronic communications process, with the application and user interface elements at the top and the physical connection standards at the bottom.

Figure 13. Open Systems Interconnection (OSI) Model (From International Organization for Standardization)

2. Mapping the OSI Model to HAN

Realizing a correlation between the OSI Model and networking in HAN environments helps foster an understanding of how HANs will interface and interoperate with other networking technologies. Establishing congruency between HAN and existing, familiar networking standards and architectures facilitates gaining an appreciation of the eventual challenges for implementing an operational HAN environment.

a. OSI Layer 1 to HAN Layer 1

The HAN standard at the physical layer defaults to the capacity of transmitting data via the human body. No reasonable alteration of this medium will improve its performance. Establishing a standard number (e.g. RS-232, T1) for the human body acknowledges its physical characteristics as a transmission medium and the constraints within which HAN must function.

b. OSI Layer 2 to HAN Layer 2

Currently, the Data-Link layer of HAN purports perhaps the most nebulous state; however, it remains a work in progress. IEEE established a working group subordinate to the 802.15 standard to investigate potential standards that might apply to what they term "Body Area Networks (BAN)," which is synonymous with HAN; however, no IEEE standard, draft or final, has been published to date. Devices designed according to this [eventual] standard will communicate with other similarly designed devices by transmitting and receiving data through the human body.

c. OSI Layer 3 to HAN Layer 3

An IP addressing standard enables disparate HAN devices to interconnect. The IP service on a HAN device will define the datagram, the basic unit of transmission in the Internet. It will also define the HAN addressing scheme, move data between layer 2 and layer 4, route datagrams to remote hosts, and fragment and reassemble datagrams. Internet Protocol version 6 (IPv6), the successor of IPv4, contains a much larger address space with the flexibility to assign multiple, unique addresses to every person on the planet.

d. OSI Layers 4-5 to HAN Layer 4

HAN management at this level uses TCP for transferring data which, as a connection-oriented protocol, establishes and tears down connections between devices. Additionally TCP provides data accountability and integrity by reassembling disordered data into the proper order, discarding duplicates, and requesting retransmission of dropped or missing packets. While these protocols provide the functionality required to exchange data on HANs, the pervasiveness of this protocol combination also offers inherent scalability to the internet and other similarly designed networks.

e. OSI Layers 6-7 to HAN Layer 5

At this layer, the network interface's HAN Application handlers dispatch data to the requested services. These services process the data into usable information and present it to the user.

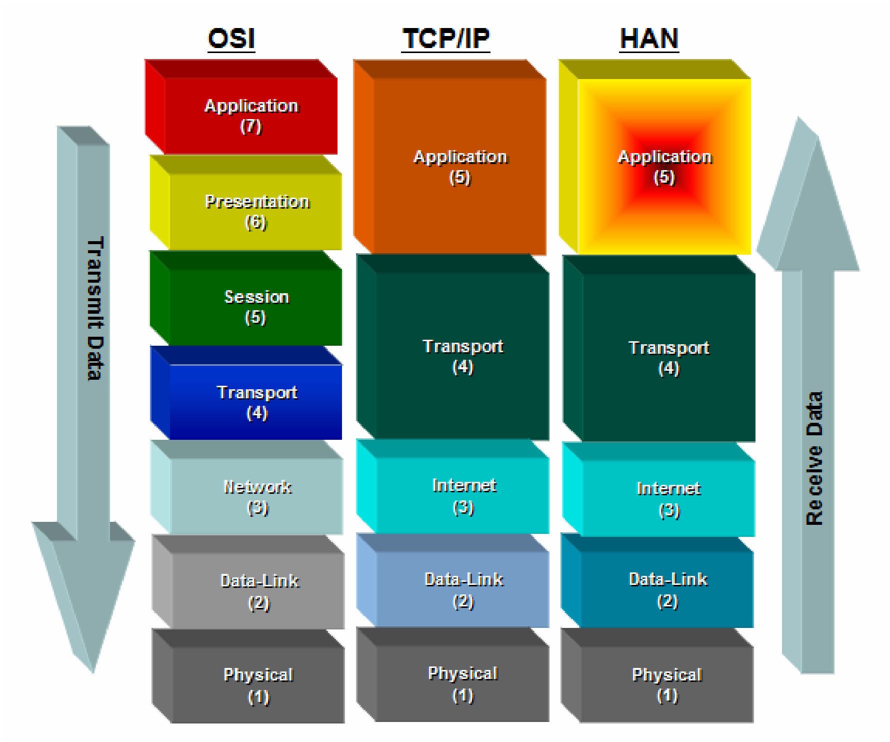

Figure 14. Model Comparison: OSI to TCP/IP to HANNA

Recalling the "Five Main Building Blocks of a Telecommunications Network" presented earlier, Table 3 describes the same fundamental blocks as they exist in a Human Area Network. Comparison of these two tables yields several "big ideas." First, several building blocks (Terminals, Transmission Links, and Architecture and Standards) do not intersect the building blocks associated with traditional networks. This is proof positive that HANs are a significant departure from any preceding networking technology. Second, some of the HAN building blocks already exist. In the case of the Transmission Links building block, the standard is pre-ordained by design of the human body. Research, application, and commercial acceptance matured and standardized multiplexing, digital signaling, and packet switching technologies. Finally, no Terminals or Standards and Architecture exist for HAN. If nothing else, this point reinforces the need for a well-laid plan to carefully develop this new technology.

	Building Blocks	HAN Examples
Five Main Building Blocks of a Telecommunications Network	Terminals	A user's HAN device and any HAN enabled peripheral, including another HAN user's HAN device. (See Figure 16)
	Transmission Links	Human skin.
	Transmission Protocols	Packet Switched, Digital.
	Nodes and Switches	Multiplexers.
	Architecture and Standards	IEEE assigned a working group to explore potential BAN standards. An architecture for development of HAN technologies does not exist.

Table 3. HAN Building Blocks (modified from Table 2)

3. A Model for Human Area Network Nomadic Agents

Figure 15 unveils the development model for a Human Area Network Nomadic Agency (HANNA). More than a clever representation of the human body, this model incorporates metaphor into every element. The lower extremities symbolize the foundation of HANNA and emphasize the importance of a thorough and complete functional and quality attribute assessment prior to developing core components of HANNA. The model's trunk addresses software and hardware components or, the heart of HANNA, which are sustained by this strong base of functional and quality attributes. Architectures appropriate to the development and growth of HANNA are represented by the model's upper extremities. Arms enable people to interact and manipulate their world. Similarly, developing HANNA components according to a Product Line Architecture coupled with component integration and subsequent employment of products under a Service Oriented Architecture approach enables diverse and intuitive interaction in the HANNA environment, fosters scalability of components, and eases development and introduction of additional technologies through the reuse of standard components. Finally, after carefully assembling the formative components, an operational HANNA environment emerges. Represented by the head of the model, this new area centers on the minds of users by enabling interaction with potentially any appliances or objects in his immediate surroundings and delivering desired information from those objects directly to the individual.

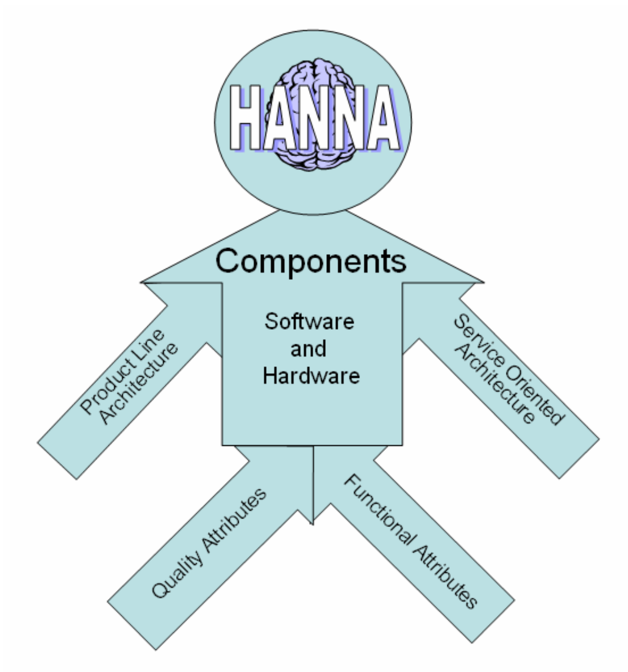

Figure 15. HANNA Architectural Model

C. HAN FUNCTIONAL AREAS

1. HANNA Environment

The HANNA environment encompasses humans interacting with HANNA Enabled Devices (HED). Humans enter HANs through a special-purpose HED, called a HANND (Human Area Network Nomadic Device). These HANNDs provide the ability to interact with HANNA enabled components, other humans carrying HANNDs, secure space access points, computers and their peripherals, etc.

HANNDs, worn on the human body, contain agents (HANNA) that maintain and update several models pertaining to the user, task knowledge and the environment. Combined, these models provide context when interacting with HEDs. Standard interfaces, such as electrodes permitting data exchange using IBC within HANs, facilitate the interconnection between a HANND and the various functional HEDs depicted in Figure 16. The center of this diagram depicts a human node as the hub who by wearing a HANND, becomes empowered to interact with any of the following HEDs at the end of each spoke simply by picking them up. With this model, the deliberate, intuitive act of interacting with HANNA computing appliances introduces a whole new paradigm that redefines familiar functionalities.

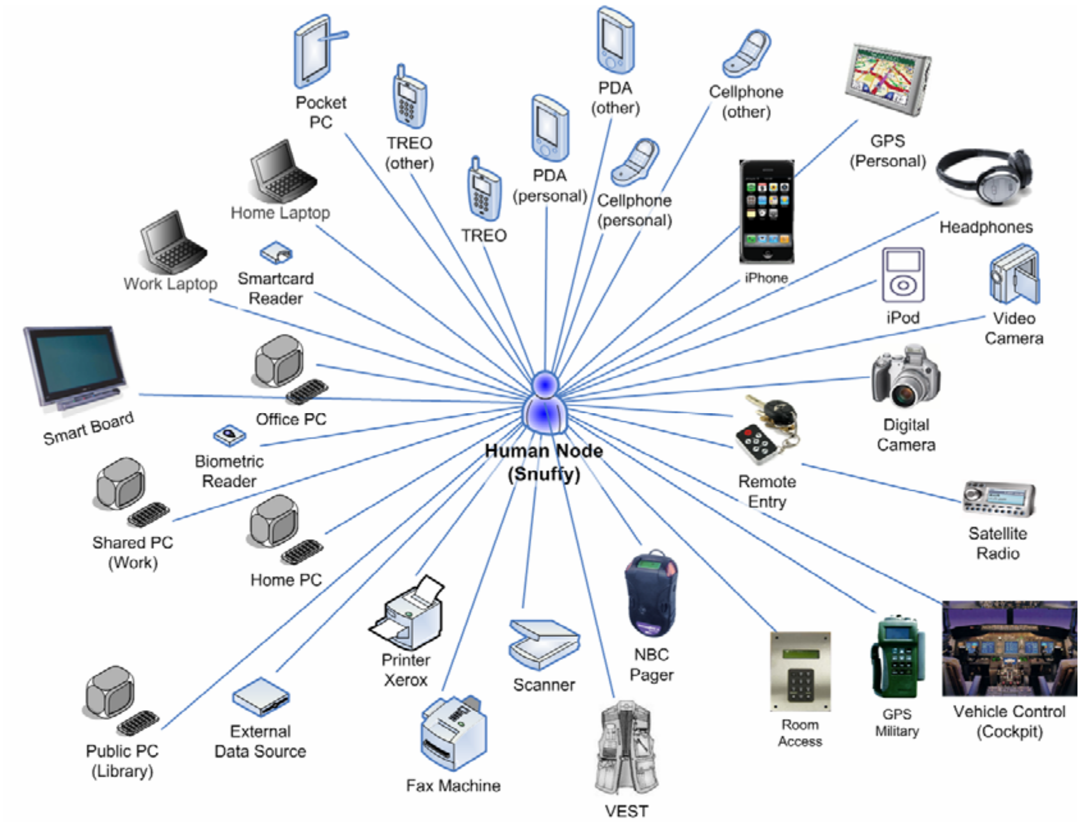

Figure 16. HANNA: Linking HANNDs with HEDs

2. HANNA Functionality

Functionality is "the ability of a system to do the work for which it was intended. Performing tasks requires that many or most of the system's components work in a coordinated manner to complete the job" (Clements 2002, 31). Software and hardware designers must imbue the HANNA concept with numerous capabilities in order for it to manifest into a real and usable network. At a higher level, these capabilities are called functions. At lower levels, these functions are iteratively dissected into smaller sub-functions until the associated descriptions convey enough discrete and measurable information for designers to build, test and implement.

Fundamental differences exist in HANNA functionalities as they relate to the various layers of the HAN communications model. In an effort to promote clarity, the following section separates communication functions (HAN), pertaining to Layers One through Four of the HANNA communications model, and application functions (NA) which relate specifically to Layer Five (see Figure 17).

Figure 17. HANNA Functionality Breakdown

3. HAN Functions

Two nodes that want to communicate with each other must each possess the necessary programming and hardware associated with establishing connections. It follows that HEDs must also possess some functionality before they can exchange data. Consider the following use case from the military scenario (future) in Chapter I: Sgt Snuffy sits down at the table and 'touches' the computer. An extraordinary and very complex event transpires in the minuscule span of time between Snuffy's contact with the computer and his subsequent authentication. Figure 18 demonstrates the component functions within this exchange that establishes an information networking connection between a HANND and a HED. Subsequently, each step is described.

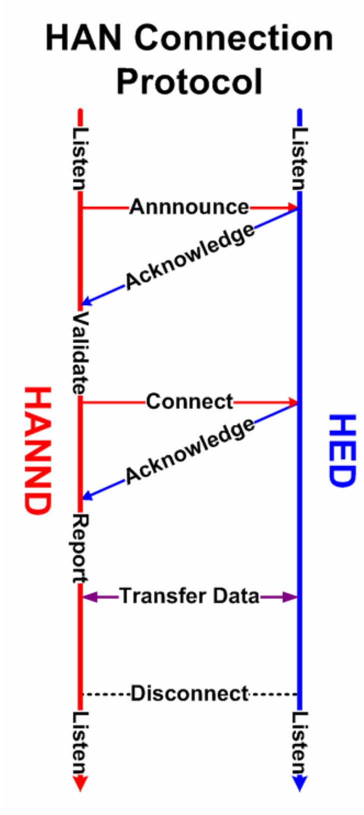

Figure 18. HAN Connection Protocol

a. Detect the Touch

Two HEDs that do not share an established connection are said to start from zero-state. These devices must first sense human contact. Functionally, a HANND must periodically announce its presence. This should happen frequently enough that a person who touches a HED could establish a connection in less than one second. Additionally, the capacity to transmit this announcement should be unique to HANNDs, since the human constitutes the hub of the network and therefore remains an integral component for HEDs to communicate. Consequently, all HEDs must continuously listen for these announcements in order to form connections.

b. Establish Precedence

Subsequent to two HAN nodes realizing each other's presence, they must establish precedence. Precedence serves the purpose of determining which device will be responsible for completing the remainder of the network formation process. In the case where a HANND communicates with a HED, the HANND will assume the role of master. If establishing a HANND to HANND connection, then the HANND that initially established communications by announcement will assume the role of master.

c. Connect to Device

Next, the devices must form a communications channel through which application data can pass. Two situations could play out at this stage: (1) the devices have connected before or (2) the devices have never connected before. In the latter case, a process begins each time the HANND detects a new, unfamiliar HED that configures how the HANND should handle future connections to the new device. By default, the HANND prompts the user to indicate his intent with the new connection: accept or decline. After making that selection, the HANND asks the user to configure the default behavior for establishing subsequent connections with this HED. The former case refers to situations where the above process already transpired thereby facilitating rapid connections with 'familiar' HEDs.

These two situations imply several functions. First, they suggest that HANNDs can discern, with certain degrees of confidence, one HED (to include other HANNDs) from another. Utilization of a Media Access Control (MAC) address associated with a HAN Interface Device (HID) solves this problem. The second implication provisions a capability for logging prior interactions where the HANND logs every previously established connection into a HAN Interaction Table (HIT). The third implication provides for the implementation functionality which accesses the HIT and configures behaviors for different connections, e.g., establish automatically every time or prompt user every time. The fourth implication establishes a requirement to configure the

HIT’s default action for new connections. For security purposes, all devices should be programmed to deny promiscuous connections by default, but allow certain devices to accept promiscuous connections to satisfy the requirements of devices designed for public use, like copiers at a print shop.

d. Notify Higher Layers

Once the HID successfully establishes the network connection, the HANND should notify the user of the network status. Additionally, the HANND should alert automated applications which utilize the network so that they can resume from idle and communicate any necessary information. If the network connection cannot be established, an alert should provide initial notification to the user followed by some form of descriptive feedback.

e. Disestablish Connection

The HID perceives network persistence in order to transmit and receive data from the transport layer. When a user stops touching the device or person that he communicated with, the network physically disconnects, but in order for the HID to sense that physical disconnection it must confirm that state by observing other metrics. Basing the determination of network status on the presence or absence of a carrier signal limits the capacity of a HANND to connect to multiple HEDs. One possible solution requires a function to monitor the state of TCP connections and report to the HID. If several TCP connections to a single device simultaneously time out, the HID assumes that network link has disconnected. After the HID senses the disconnection, it should notify the user and automated services of the network status. Applications designed to function over this network must be designed to degrade gracefully in the event of disconnections.

f. HAN Services

A HED’s ability to perform intuitive services significantly expands its capability. For example, recall the following use case from the military scenario (future) where Sgt Snuffy’s HANND automatically configures his radio with the proper frequencies. The radio handset, a HED, possesses much more capability than simply providing a conduit for voice or digital communications. Snuffy's actions are deliberate, empowering devices to execute certain scripted actions when the user alerts them through the power of touch. These invisible, intuitive functions are HAN services. In Snuffy's case, the radio performs an automatic configuration service that utilizes information from Snuffy's HANND to program frequencies into the radio for the current mission. If Snuffy passed his HAN enabled radio to Corporal Gruffy, a Marine in another platoon executing a different mission, the radio would automatically reconfigure to meet Gruffy's communications requirements.

HEDs require a robust service management capability. Any HED could be capable of one or more services. Some services may execute by default, and some may require user selection. The HED may advertise some of the services to all users, while other services exist for administrators only, and still other services may avail themselves upon request. When a user connects to a HED that offers multiple services, the user can, depending on configuration, take advantage of zero, one, or many services. Utilization of a "Service Classification Scheme" provides one possible method of managing many services. A classification scheme permits a HED to tell a HANND exactly what services it can provide. Additional capabilities that a Service Classification Scheme accomplishes include permissions control of services and version control of software (e.g., I have a "Classified Space Access Service," but not the newest version). Regarding security, the system should incorporate additional levels of authentication, e.g., CAC, fingerprint, PIN as well as perform Layer Four encryption for extended confidentiality (SSL).

4. "Nomadic Agency" (NA) Functions

The functional areas that follow correspond to the "NA" in HANNA as they relate to Layer Five (Application) of the HANNA Communications Model. These functionalities provide developers with a framework for "what" [multiple] Agents within the "Agency" of HANs should accomplish (see Figure 19).

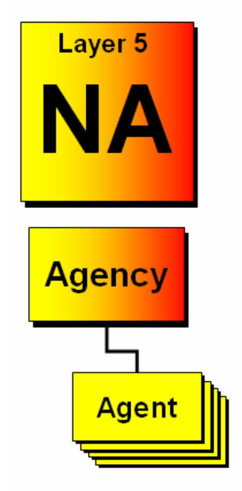

Figure 19. Nomadic Agency Breakdown

The “N” portion of the latter HANNA acronym reveals one meta-function relating to all other specific applications functions. “Nomads” move from place to place across their environment as opposed to settling in one location. With respect to the design of today’s personal devices, one might argue this concept reveals nothing different from portability. That notion, however, implies the ability for programs to run in various environments and operating systems, or specifically, a certain measure of independence in the sense that programs can move and operate on new systems without reconfiguration. In the case of HANNA, the devices one carries are certainly portable, in accordance with the above definitions, with the distinction that, like a nomadic community of people, HANNDs transport their entire “life” on their backs. Instead of [human] physical belongings, associated relationships, and personal memories, HANNDs retain and continuously update user model knowledge, task knowledge, and knowledge about various environments.

Use cases, extracted from the military mission planning and execution scenario (Chapter I) reiterate these nomadic capabilities and provide a foundation from which to grow existing functionalities or add new ones as they are discovered and/or needed. Currently, the NA functions include the intelligent automation of: Decision Support, Tasking, Communicating, Situational Awareness, and a Feedback Mechanism.

a. Decision Support

Decisions in life range from simple to complex. Complicated decisions typically require robust analysis processes preceded by exhaustive information gathering and subsequent processing before individuals can settle on suitable courses of action. Conversely, simple decisions require minimal human processing power and absorb significantly less time due to less severe penalties. In the end, the energy and time invested in the entire process correspond directly to the decision's consequences. Regardless of the scope, reaching sound decisions consumes precious resources in terms of time, money and manpower, all three of which are heavily guarded in both civil and military arenas.

Military decisions span the spectrum of complexity and pervade all operations beginning with formalized planning processes and continuing through the execution of missions. HANNA facilitates the preservation of valued resources by automating the processes that contribute to sound decision-making in a manner transparent to the user/customer. These include, but are not limited to: collaborating with other planners or planning systems (man and machine), rapidly accessing data from historical and current planning databases, disseminating information vertically and horizontally in the right format at the right time, and tailoring data presentation to the individual the agent supports.

When Sgt Snuffy conducts mission planning in the military-based scenario (future), several decisions are automatically made which are transparent to Snuffy. The collective outcome of these decisions yields a thorough analysis at a minimal cost of time to Snuffy. Consider the following use case: Sgt Snuffy clicks on Step 1: Mission Analysis, which displays a top field containing several specified tasks in bold and a second field listing suggestions for implied tasks. The top field cannot be manipulated, as these were assigned by HHQ. The agent populates the second field according to the current mission type, incorporating Sgt Snuffy's past experience in similar missions (retrieved from the device on his body) and adjacent unit After Action Reviews (AAR). In contrast to the top field, the second field allows the user to select and/or add tasks.

Sgt Snuffy's HANND exchanged resident, historical data based on his user model and environment in a manner that fulfilled the task of populating a field with relevant, non-redundant information. The planning system extracts Snuffy's data through touch (IBC), combines it with data from other systems and filters out similarities before presenting a consolidated, clean list to Snuffy. The time it would take a person to collect and fuse this amount of data from disparate systems (let alone make subsequent decisions on what to include or discard) demands too much from Snuffy.

b. Tasking

Tasking follows decision-making with particular focus on coordinating the effective and efficient employment of assets and resources to execute decisions. With HANNA, tasking becomes automated once users assign delegation authority to a HANND. Historical context, based on one's user, task knowledge and environmental models, further facilitates the automation feature by ensuring HANNDs accept or respond to tasks in a manner congruent with user expectations. Figure 20 depicts the relationship between these various elements and tasks.

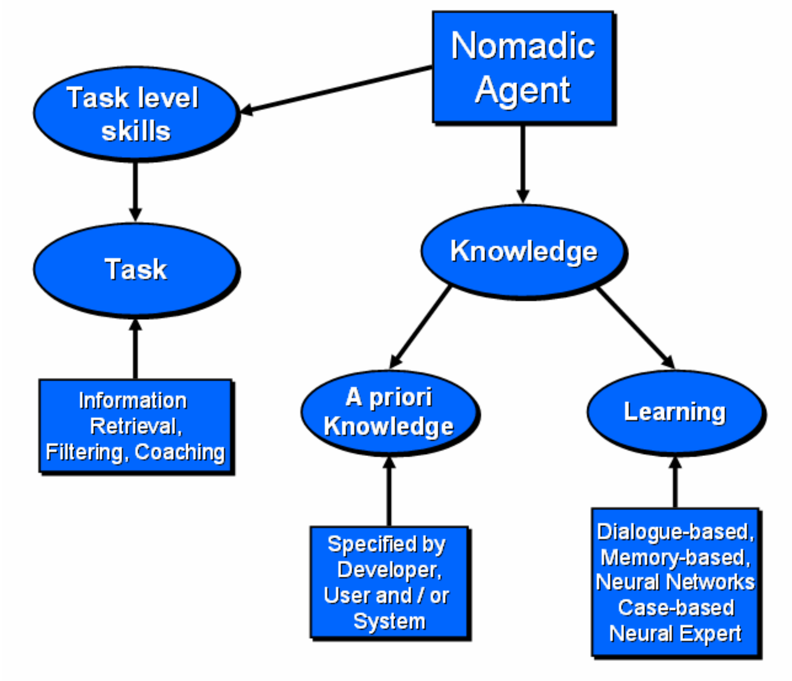

Figure 20. "NA" Task-Knowledge Model (After Hayes-Roth *Radical Simplicity* Figure 7.2.)

Tasking sub-functions include, but are not limited to the ability of Nomadic Agents to:

- Receive and assign tasks
- Prioritize and automatically optimize task lists
- Assess task:
    - Suitability –the Agent can accomplish the task given certain constraints
    - Feasibility – the Agent possesses the capability to accomplish
    - Acceptability – the resources needed to accomplish are agreeable
    - Completeness – in addition to who, what, where, when, how, does the Agent require additional input to accomplish the mission?
- Inform users when it cannot unilaterally accomplish a task
    - Recommend other [nearby] resources that can assist and how to connect, task, or request those additional resources
- Recognize and subsequently accomplish related [implied] tasks that fit the user model (preference, history, context)
- Deconflict with other agents to mitigate redundant allocation of multiple [limited] resources

Some of these sub-functions are visible in the military-based scenario (future) when the Marine takes a digital photograph during an R&S mission. Consider aspects of tasking, highlighted in brackets (e.g., [highlightTask]), in the following use case adapted from that scenario: After taking the photo, the Marine touches a menu dial on the back of his camera to tag the photo for e-mail [tagImage], The Marine's HANND populates the camera's LCD with a list of addresses [getAddresses] [displayAddresses] and selects the Intelligence Officer as the recipient [transfer] [tagImage] [email] [draftMessage]. As the file transfers to the Marine's HANND from the camera via IBC, the GPS on his vest sends his current location/orientation [getPosition] [addPosition] [tagImage] to be encoded as metadata on that image file.

The implicit tasks in the above example are automatically screened, accepted, evaluated and fulfilled, relieving an already resource-strained operator to expend remaining energy focusing on his physical surroundings. Each new task generates opportunities for learning. The Agent capitalizes on these opportunities and updates the user's knowledge, thereby empowering the Agent to accomplish a wider array of tasks (Figure 20).

c. Communicating

The function of communicating facilitates information exchange and justifies the very existence of networks. Systems must accept inputs, display outputs, and, with respect to HANs, facilitate these interactions between man and machine. This function naturally follows the first two as it provides the means to disseminate results of decisions and receive/assign tasks. HANNA should facilitate real-time collaboration between people and systems using several combinations that maintain the user's centrality in the process (man-to-machine, man-to-man, machine-to-machine) in a manner that remains transparent to the user.

Autonomous communication helps spare users information glut by discerning the relevancy of information before making notification. For example, in the case of Sgt Snuffy's information requirements, only changes to the enemy situation are necessary. This requires an Agent to possess the existing enemy situation model for comparison. The "Knowledge" element of the NA Task-Knowledge Model (Figure 20) provides this foundation and when coupled with the NA Communications Model (Figure 21), enables the Agent to accept or deny future communications pertaining to this rule.

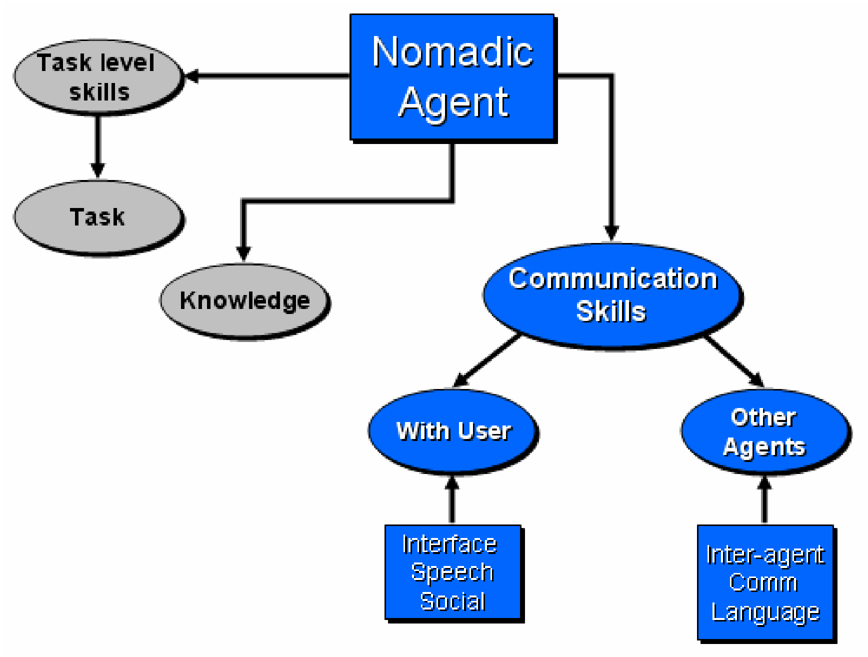

Figure 21. "NA" Communications Model (After Hayes-Roth *Radical Simplicity* Figure 7.2.)

Removing the human element, in the specific instance mentioned above, accelerates the communication and subsequent decision-making process. Continuously updating the model's elements ensures decisions and tasks are made, accepted, and disseminated after accessing the most current contexts available. In addition to faster "sense-act" loops, the Agent also decreases time to "act" by alleviating the [human] burden of knowing "who" to contact and how to reach them. The Agent automatically communicates with those entities when it detects connections to devices that span domains outside of the HAN. Figure 22 depicts notional relationships between various computing models, centered on the user, that span the scale of networking models. "Depending on the machine's capabilities, given tasks can be executed by the appliances autonomously or they can pass on certain subtasks to Web services over the Internet" (Hayes-Roth 2003, p 155).

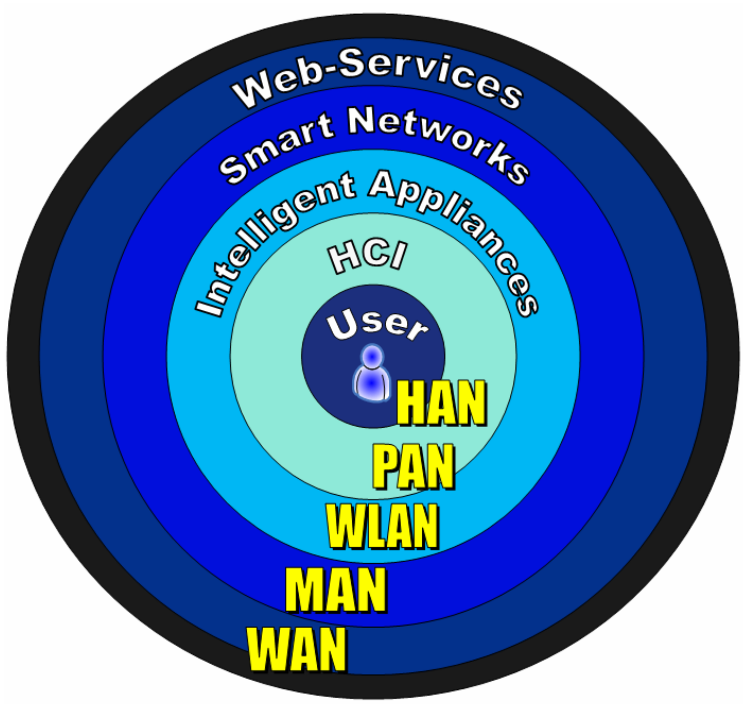

Figure 22. HANNA Communications (After Hayes-Roth *Radical Simplicity* Figure 5.1.)

This functionality enables the Marine's digital photo and associated data to transfer to the e-mail application running on his laptop via IBC with subsequent delivery via UHF satellite link to the Intelligence Officer, 20 miles away. In this sense, the networks and associated services with which humans carrying HANNDs interact define scalability limits to HANNA, rather than the act of physical touch itself.

d. Situational Awareness

Situational Awareness (SA) comprises the mental representation of "objects, events, people, system states, interactions, environmental conditions, and other situation-specific factors affecting human performance in complex and dynamic tasks." Simply put, SA equates to "knowing what is going on so you can figure out what to do" (Adam, 1993). A polysemous term, SA maintains historical roots in command and control (C^2) theory and could be the subject of separate thesis by itself.

The SA function in HANNA refers to monitoring and sensing the environment for the purpose of updating the Agency's environment model. This context-based element also coordinates with the task knowledge and user model elements to synchronize what information HANNA currently knows versus what information HANNA seeks. This process could be summarized as "the combining of new information with existing knowledge in working memory and the development of a composite picture of the situation along with projections of future status and subsequent decisions as to appropriate courses of action to take" (Fracker, 1991). Fracker's description of SA coincidentally incorporates the decision-making, tasking, and potential communications functions of HANNA, but leaves the automated characteristic to the imaginations of others.

The process of HANNA's ability to intelligently sense its surroundings, rapidly filter massive amounts of data, and selectively incorporate key bits into its models (user/task knowledge) must remain invisible to the user. Dynamic environments, like combat, present unique challenges to doing this successfully. HANNA does not advertise "crystal ball" capabilities, but rather, facilitates the individual decision-making process by intelligently deducing relationships between current and scheduled events as well as considering anomalies that may introduce new events. This function further enables the automation of [projected] task delegation as well as the presentation of updated candidate plans from which the user can choose to adjust or direct new courses.

Coordinating future missions with the intelligence section in the military scenario (future) reveals HANNA's SA functionality. Sgt Snuffy views a list of the projected tactical and theater-level collections assets that will be operating in his AO during an upcoming mission. This list includes: other R&S teams, micro-UAVs, and HUMINT teams. Depending on Snuffy's clearance level, the collections "deck," or intelligence assets schedule matrix, downloads via his hand (IBC) to his HANND. Additionally, Sgt Snuffy's mission profile (date/time of departure, projected route, collections priorities, etc.) uploads from his HANND into the intelligence system's database which then disseminates the information to those previously mentioned collections assets. This crude attempt at "shared SA" becomes more refined as sensors collect and begin to report across the battlefield. HANNA reveals its value as it cleverly filters incoming data and only presents information from other assets that bear relevance to Sgt Snuffy's collections priorities.

e. Feedback Mechanism

The Feedback function accepts outputs from other functions, as its inputs, and passes them back to various functional areas as new inputs designed to improve the overall process. At this juncture, information flow represents the current state of the model. Within the Feedback function, updated situational assessments are combined with present conditions then compared to previously received states. Detection of significant changes may then prompt recommendations to the other functional areas. In this sense, a Nomadic Agent's feedback function is no different from the notion of a traditional feedback "loop." Figure 23 graphically portrays the relationship between Feedback and the other four Nomadic Agency functions.

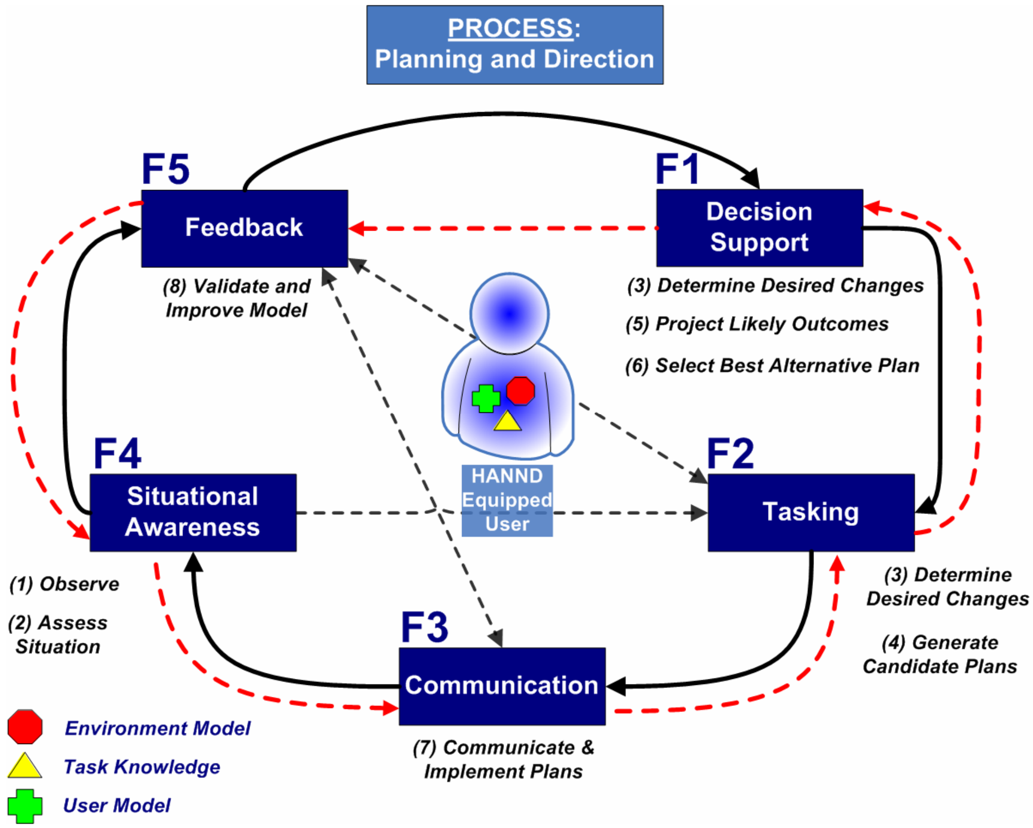

Figure 23. Nomadic Agency "Function" Model

This model also integrates the elements of "Efficient Thought" described in Chapter II (Figure 5) as they pertain to automated decision making support in the HANNA environment. As suggested, Feedback's function exists to "validate and improve the model" but in this case, the improvements are made in terms of updates to the various sub-components of the HANND, i.e., User Model, Task Knowledge, Environmental Model, etc. Feedback can also monitor the status of various tasks (F2) including their feasibility, suitability and degree of completeness. Another capability of Feedback could include auditing inputs for the sake of reinforcing data accuracy within the model(s). Feedback outputs may vary from audible alerts to visible messages to tactical sensations felt on the body (TSAS). This last method is demonstrated in the following use case extracted from the military scenario (future): The six-man [Recon] team enters and splits into two groups. The hallways and rooms are dark and neither element possesses a blueprint of the building's layout. The two teams converge at the end of a dark, maze-like hallway, weapons at the ready when the TL receives a slight vibration in the upper right quadrant of a vest he is wearing. The familiar tactile sensation alerts him to the presence of nearby friendly forces. He gestures to the others to lower their weapons. Without instant feedback, based on previous tasks autonomously coordinating with situational awareness functions, the results of this link-up could have resulted in serious injury or death.

D. HANNA QUALITY ATTRIBUTES

Quality Attributes (QA) define "properties of a work product or goods by which its quality will be judged by the stakeholders" (SEI Glossary). Representing the left leg of HANNA's Architectural Model (Figure 15), QAs represent those product aspects that stakeholders deem most important to success, delivering expected results or avoiding unacceptable outcomes. The HANNA Architecture emphasizes the following QAs: usability, interoperability, security, maintainability, and portability. Other QAs may apply, but these attributes incorporate the most essential quality requirements pertaining to HANNA.

1. Utility Tree

Utility trees provide a top-down, structured method for characterizing the 'driving' attribute-specific requirements in architectures (SEI Glossary). Trees consist of nodes, which represent important quality "goals", and leaves, which facilitate the generation of scenarios exemplifying those goals (Clements 2002, 288). According to leaders in the Software Engineering community, "Building utility trees from business goals and working toward capturing scenarios for the system qualities provides a systematic approach to capturing the qualities that are important to the architect" (Ibid, 97). In this sense, the utility tree indicates what to focus on whereas the architectural approach indicates where to focus.

Figure 24 illustrates the first three levels, called "branches," of the HANNA utility tree. This top level tree extends to the QA refinement level, but stops short of describing specific QA scenarios. The descriptions that follow are covered as separate branches and depict examples from the military scenario (future). For reference purposes, these scenario QA branches bear identification numbers in dot notation. For example, Extensibility can also be expressed as 4.3.

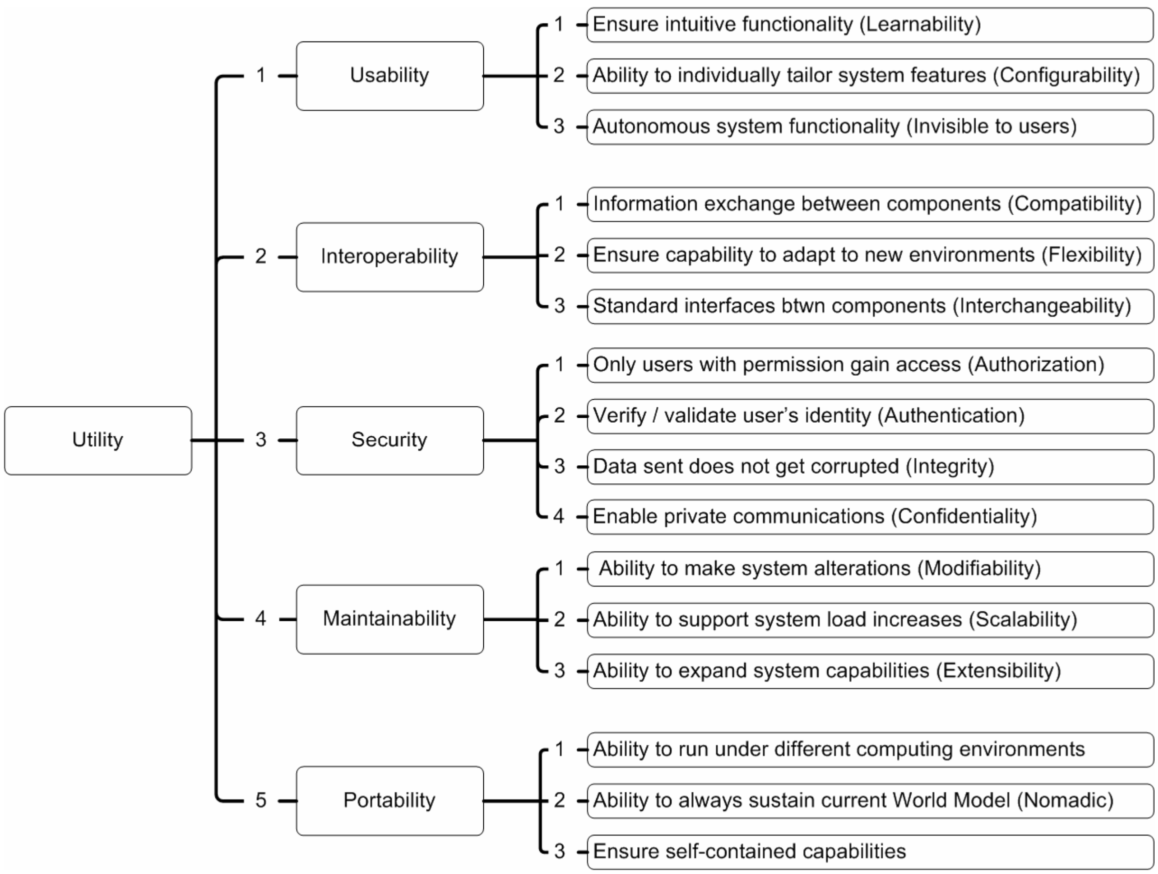

Figure 24. HANNA Utility Tree - Top

2. QA - Usability

Usability measures the ease with which users can learn to operate, prepare inputs for, and interpret outputs of a system or component (SEI Glossary). It also assesses how well users take advantage of system functionalities (Figure 25). Utility, on the other hand, measures whether that functionality does what is needed. The following QAs comprise the third layer of the Usability branch:

- Learnability– The ease with which one learns system functionality and gains proficiency to complete tasks
- Configurability– Allowing system behavior to vary by small amounts of user input; supporting the rearrangement of features and attributes
- Invisibility– Refers to the autonomy of HANNA in completing tasks without alerting the users' senses

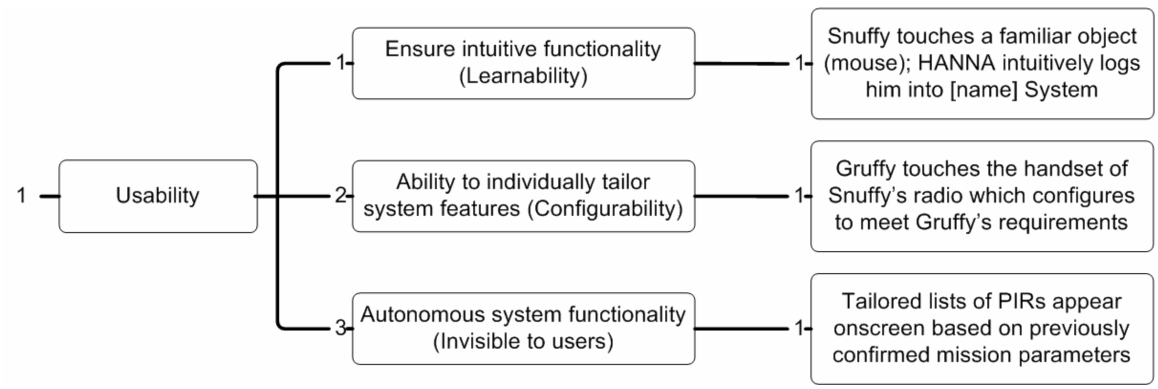

Figure 25. HANNA Utility Tree - Usability

3. QA - Interoperability

Interoperability, sometimes referred to as compatibility, also includes flexibility and interchangeability. Collectively, these QAs represent the ability of two or more systems or components to exchange information and then use that exchanged information (Figure 26). Individually, these QAs are defined as:

- Flexibility– The ease with which a system or component can be modified for use in applications or environments, other than those for which it was specifically designed (IEEE Std. 610.12).
- Interchangeability– Two or more items possess similar functional and physical characteristics that enable equivalence in performance and durability. These items can be exchanged one for the other without alteration.

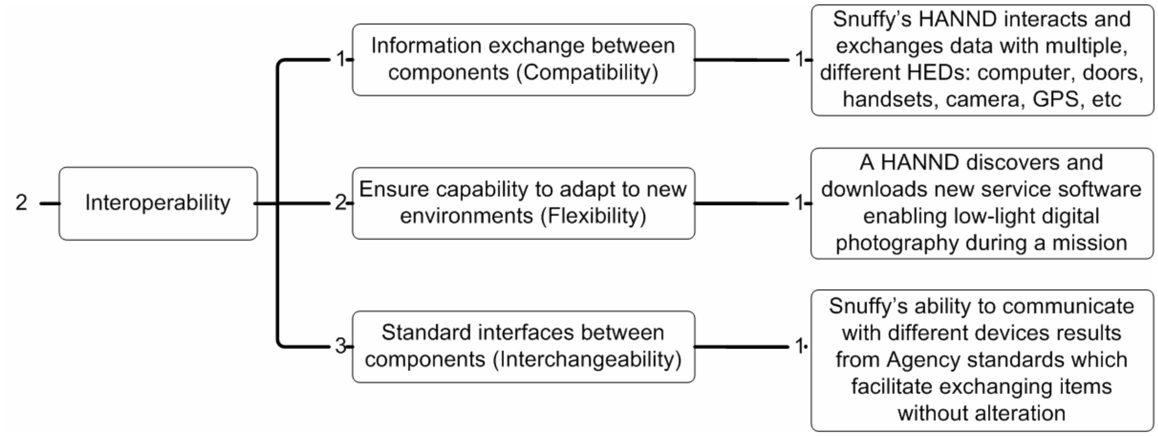

Figure 26. HANNA Utility Tree - Interoperability

4. QA - Security

Security represents a measure of the system's ability to resist unauthorized attempts at usage and denial of service while still providing its services to legitimate users (Open Wings). Often categorized in terms of the types of threats that might be made to a system, computer security can also be defined by the following principles (Figure 27):

- Authentication– Verifying the identity of a person or piece of code, i.e., certification validation
- Authorization– Verifying that a user or implementation has permission for the requested operation.
    - Allows users to dynamically manage access control to systems by simply defining roles, assigning permissions and establishing relationships with other authentication services
- Data confidentiality– Allowing private communications between parties.
- Data integrity– Information sent does not get corrupted.
- Non-Repudiation– The assurance that a principal sending data cannot deny being the sender after sending it.
- Auditing– Detecting breaches in security (Ibid).

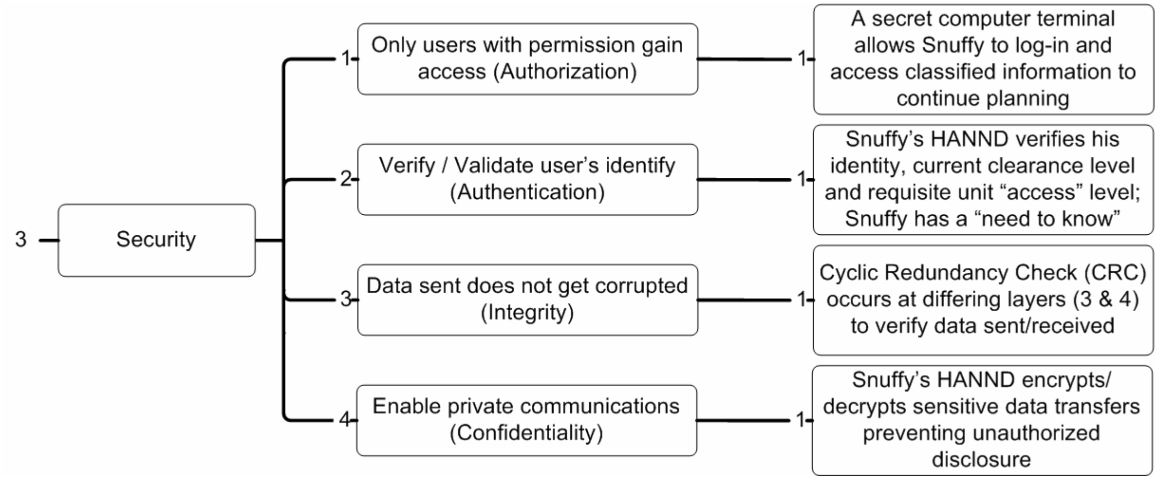

Figure 27. HANNA Utility Tree - Security

5. QA - Maintainability

Maintainability encompasses Modifiability, Scalability, and Extensibility with respect to HANNA (Figure 28). It represents the ease with which software systems or components can be modified to correct faults, improve performance, or other attributes, including the ability to adapt to changed environments (IEEE Std. 610.12). The following QAs make up the third layer of the Maintainability branch:

- Modifiability– The ability to make changes to a system quickly and cost effectively. It is measured by using specific changes as benchmarks and recording the expense of those changes (O'Brien 2005).
- Scalability– The ability of a system to support the desired quality of service as load increases without having to change the system (Ibid).
- Extensibility– The system includes all of the mechanisms for expanding/enhancing the system with new capabilities without the need to make major changes to the system infrastructure (Ibid).

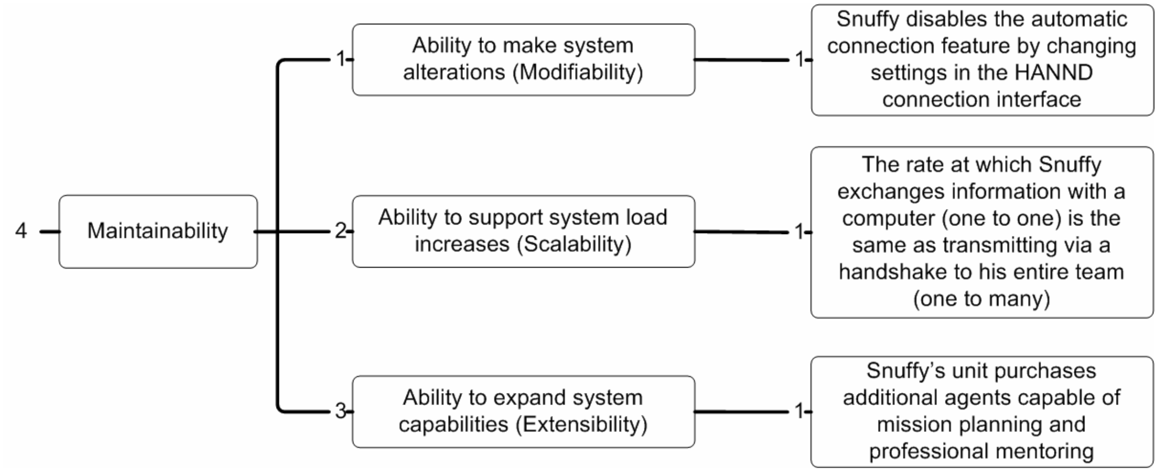

Figure 28. HANNA Utility Tree - Maintainability

6. QA - Portability

The system's ability to seamlessly operate within different computing environments marks one aspect of Portability. Environments can include hardware, software, or some combination of the two. A system is portable to the extent that all of the assumptions about any particular computing environment are confined to one component (or at worst, a small number of easily changed components) (Figure 29). If porting to a new system requires change, then portability is simply a special kind of modifiability (Clements 2002, 31).

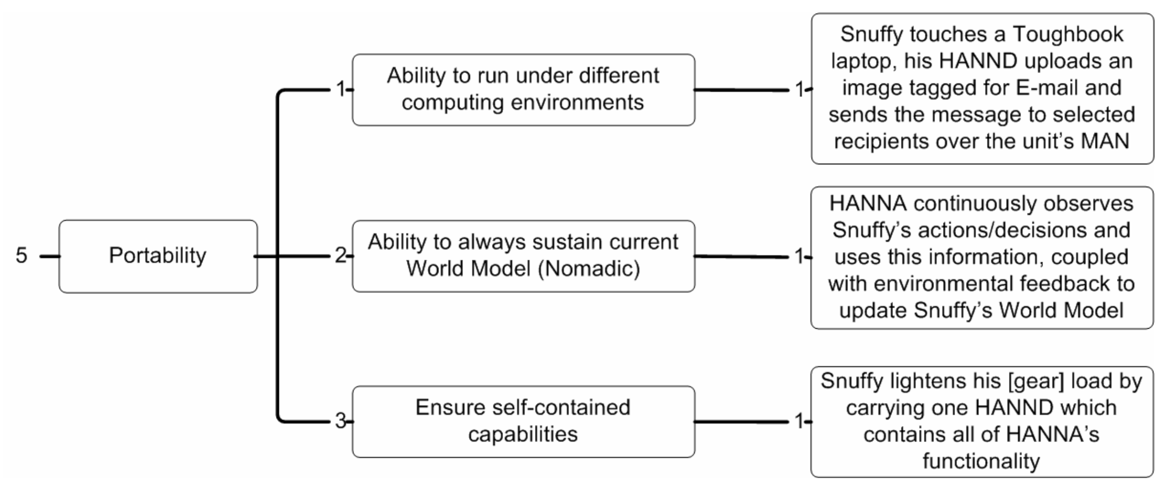

Figure 29. HANNA Utility Tree – Portability

E. SERVICE ORIENTED ARCHITECTURE

Detailed Functional and Quality Attributes provide a foundation for core component development within the HANNA Architecture. Shifting attention to the model's upper extremities (Figure 15) presents new opportunities to develop and grow HANNA as it interacts with the environment. Service-Oriented Architecture (SOA) describes an architectural approach for "building systems or applications that use a set of services and not just a system that is built as a set of services" (O'Brien 2005). "Services," in this case, represent implementations of well-defined pieces of business functionality with published, discoverable interfaces that can be used by consumers when building different applications and business processes (Ibid).

A standard, industry-wide definition of SOA does not exist, nor does an official set of service-oriented design principles. Common service-level design principles associated with service orientation, however, do exist. The following list, and accompanying descriptions, extracted from Thomas Erl and James McGovern, comprises design principles to be considered in a HANNA SOA.

Services are:

- Reusable. Regardless of whether immediate reuse opportunities exist, services are designed to support potential reuse.

- Loosely coupled. They must be designed to interact on a loosely coupled basis, and they must maintain this state of loose coupling.

- Composable. They may compose other services. This possibility allows logic to be represented at different levels of granularity and promotes reusability and the creation of abstraction layers.

- Autonomous. The logic governed by a service resides within an explicit boundary. The service has complete autonomy within this boundary and is not dependent on other services for the execution of this governance.

- Stateless. They should not be required to manage state information, since that can impede their ability to remain loosely coupled. Services should be designed to maximize statelessness even if that means deferring state management elsewhere.

- Discoverable. They should allow their descriptions to be discovered and understood by humans and service users who may be able to make use of the services' logic. Service discovery can be facilitated by the use of a directory provider, or, if the address of the service is known during implementation, the address can be hard-coded into the user's software during implementation.

- Location transparent. Service requestors do not have to access a service using its absolute network address. Requestors dynamically discover the location of a service looking up a registry. This feature allows services to move from one location to another without affecting the requestors.

(Erl 2005 and McGovern 2003).

These capabilities and design principles make the SOA approach well-suited for developing services associated with HANNA from the top level "Agency" to the individual services that enable users to interact with their world in novel ways.

F. PRODUCT LINE ARCHITECTURES

The final appendage of the HANNA Architectural Model appropriately "extends" the foundation of this thesis to include exploring the feasibility of developing a Product Line Architecture. A PLA represents a common architecture for sets of related products or systems developed by an organization. This methodology of development facilitates the adaptive and efficient creation of hardware and software components in less expensive, modular ways that promote frequent reuse. If implemented correctly, HANNA developers would end up producing more than variations of HANNDs and HEDs. A "family" of related products would emerge, including, potentially, clothes with built-in HED sensors. These products would be comprised of generic, reusable software components that interface with other existing devices. In these anticipated cases, the PLA provides a framework for how these components will interact and subsequently function to deliver new capabilities through innovative products.

In revisiting Figure 15, this chapter provided a foundation for HANNA, consisting of defining the functionality and associated QAs that support the development of various hardware and software components. In order to translate this effort into a successful PLA, initial HANNA products and their supporting applications need to materialize and then rapidly gain the trust of a firm user base. Further, as technology improvement cycles persist, stakeholders should iteratively assess and refine the requirements to ensure they still present valid and credible needs.

HANNA's first few applications will help developers refine the process to meet future needs by identifying essential components to be reused. HANNA architects can then separate these valuable components and their associated supply-chains in order to begin mapping the business side of implementing a PLA. Starting small by concentrating resources in one area that, based on empirical evidence, shows promise in benefiting a specific, influential user group, will increase the likelihood of a long-lived HANNA PLA.

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IV. PROPOSED IMPLEMENTATION PLAN

A. MARITIME INTERDICTION OPERATION EXPERIMENTS

Every quarter, Naval Postgraduate School (NPS) students and faculty engage in Maritime Interdiction Operations (MIO) exercises involving several international partners and various U.S. Department of Homeland Security (DHS) and Homeland Defense agencies. This iterative test-bed environment supports a myriad of research goals with ideal opportunities to explore the HANNA concept.

1. MIO Objectives

The objective of the MIO experiment is to evaluate the use of established and emerging, ad-hoc and mesh networks, advanced sensors, and collaborative technologies in support of conducting hasty MIOs. Primary emphasis is placed on the ability of a Boarding Party to swiftly establish ship-to-ship communications. These communications permit disseminating information regarding the rapid search for radiation, explosive sources, and personnel (biometrics) while maintaining network connectivity with C^2 organizations and collaborating with remotely located sensor experts. A major expected outcome includes providing necessary insights on how to transform advanced networking and collaborative technology capabilities into C^2 improvement (Bordetsky, et al. 2007).

2. MIO Research Tasks

The design of each MIO experiment addresses the operational, networking, and sensor technology challenges of conducting emerging network-centric maritime radiation awareness, rapid, mobile collaboration and interdiction operations. The following paragraphs summarize these main tasks as they apply to current and future experiments:

a. Operational

Conducting the MIO, including drive-by detection and Boarding Party deployment, in the open waters 3-5 nautical miles off the coast remains a main operational goal. Establishing a C^2 node to coordinate Boarding Party actions, including search and detection, facilitates mission control from remote distances. This node also enables centralized collaboration with coalition partners to include full-scale building searches (overseas) and subsequent identification of terrorist cell members. The Boarding Party must be able to perform forward-deployed biometrics identification, radiation detection, and source identification in the open-water environment.

b. Networking

Subsequent experiments will explore various capabilities of adaptive, self-forming, broadband wireless, ship-to-ship, and ship-to-shore networks in support of radiation detection and biometrics identification in the open waters. A host of networking technologies support data transmission requirements between dislocated entities including long-range, self-aligning OFDM (802.16) technology, low-bandwidth communications (900 MHz, Iridium Satellite), Sky Pilot, Quad-Iridium Links, ITT Mesh, and Ultra-Wideband in order to provide robust on-the-move capabilities for drive-by/detection assets. Internal to the Boarding Team, however, the status quo for sharing data consists of "sneaker-net" or "thumb-drive-net" where individuals pass data, collected from various hand-held sensors, via USB 2.0 thumb-drives. HANNA and touch-technologies represent a suitable, soon feasible solution to accelerate this process while improving individual situational awareness levels. Figure 30 depicts the macro-level MIO Network which includes previously mentioned WAN, MLAN, WLAN, and LAN paradigms and adds a recommended HAN within the Boarding Vessel node.

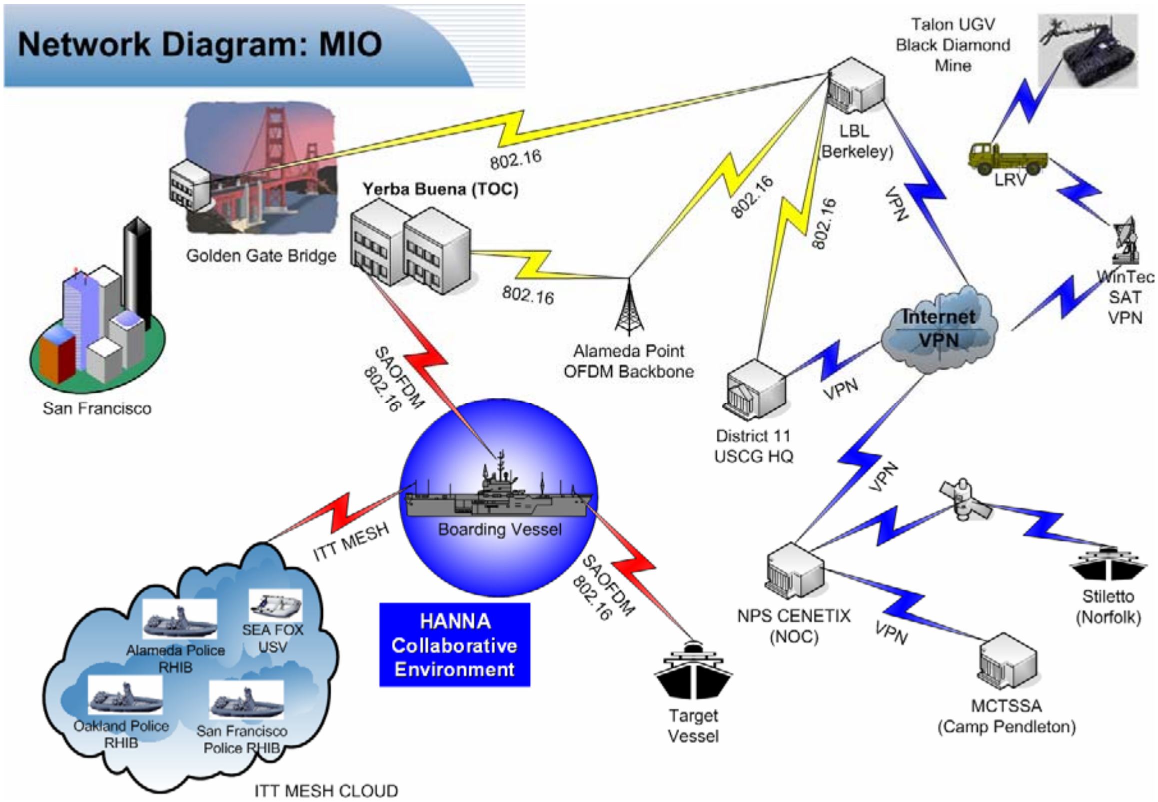

Figure 30. MIO Network

A future, experimental networking objective includes augmenting the collaborative environment with innovative tools that not only enable end-to-end robustness of collaboration with boarding parties in open waters, but do so more quickly and efficiently. The Principal Investigator for MIO and Director of the Center for Network Innovation and Experimentation (CENETIX), Dr. Alex Bordetsky, facilitates the integration of these innovative technologies. In a letter to Dr. Socomoto of Red Tacton, Dr. Bordetsky offered the NPS-run test bed as a platform to evaluate HAN and data transmission by touch as part of the self-forming mesh networks supporting highly mobile human operators (Bordetsky 2006). CENETIX should persevere with Red Tacton and other vendors in order to explore the "major operational constraints and benefits of integrating 'transmission by touch' into mobile tactical networks" (Ibid).

c. *Sensors*

Disseminating and sharing increasingly complex sensor data provides the impetus for the previous section. Future experiments intend to explore stand-off sensor detection limitations for nuclear, radiological, and explosive materials. Other assets include pneumatically-launched, projectile-based sensors discharged from the individual shoulder in multiple-round bursts during drive-by detection phases of the MIO. On board the target vessel, the Boarding Team will integrate the Swedish Navy portable sensor-vest containing radiation/explosive detection sensors, video, and biometrics. This node, much like the aforementioned TSAS (Chapter Two), facilitates the Boarding Party's ability to network and collaborate with responders in a "hands-free" manner.

HANNDs, equipped with commercial off-the-shelf sensor technology, offer another tipping point for accelerating decision cycles while facilitating the environmental situational awareness of Boarding Team members. As collaboration migrates away from 'fixed' workstations (laptops) and into the wireless realm, hands-free devices (particularly in evolutions that require maximum use of both hands) will gain popularity. HED "collaborative personal communicators (CPC)" have the potential to transfer data wirelessly through common peripheral devices equipped with Bluetooth or IBC technologies (Figure 31).

Figure 31. HANND: Collaborative Personal Communicator

This [notional] CPC consists of a wireless earpiece, microphone, and digital 'pen' camera capable of video and still imagery. Data transfers from the earpiece to a storage device worn on the body for archival purposes or while awaiting transfer to another CPC or PC. The device permits Boarding Team members to use both hands while eliminating the need for cumbersome [Pelco, etc.] cameras. It also reduces the time required to download, transfer (USB, Flashcard, etc) and pull up digital photos using photo editing applications before transferring files to appropriate parties.

d. Collaborative Technology

Microsoft Office's Groove remains the backbone collaborative technology application utilized by the Boarding Team to disseminate sensor data collected during MIOs. Historically, the Boarding Officer simultaneously monitored several Groove workspaces while managing robust tool sets and integrating sensor data from multiple Boarding Team members via "thumb-drive-net" techniques. Pursuing simpler solutions and streamlined applications to accomplish these tasks remains a goal in this category (Rideout and Dash, et al 2006). Other collaborative tools, including Jabber, CENETIX video conference (VC), and MIT's Electronic Card Wall (EWALL), represent additional options available for future experimentation.

B. INTEGRATING HANNA INTO THE MIO

The role of the Boarding Officer billet represents a logical starting point to implement HANNA in the MIO environment. This officer resides at the hub of collaboration with humans and systems as he/she assumes responsibility for supervising the following:

- Collecting, processing, and posting biometric matches and photos to the National Biometric Fusion Center
- Collecting, processing, and posting radiation files and photos of sources
- Collecting and posting responses from expert evaluations into collaborative software applications

- Analyzing and comparing radiation spectrum files from remote experts
- Tracking radiation materials
- Sharing atmospheric modeling and predictions with remote experts
- Posting recommendations on Boarding Party further actions when additional search requirements surface

1. Exchanging Data Using HAN-IBC-Enabled Devices

Figure 32 provides an extension of Figure 30 with emphasis inside the HAN-enabled portion of the MIO Network, the Boarding Party aboard the Target Vessel.

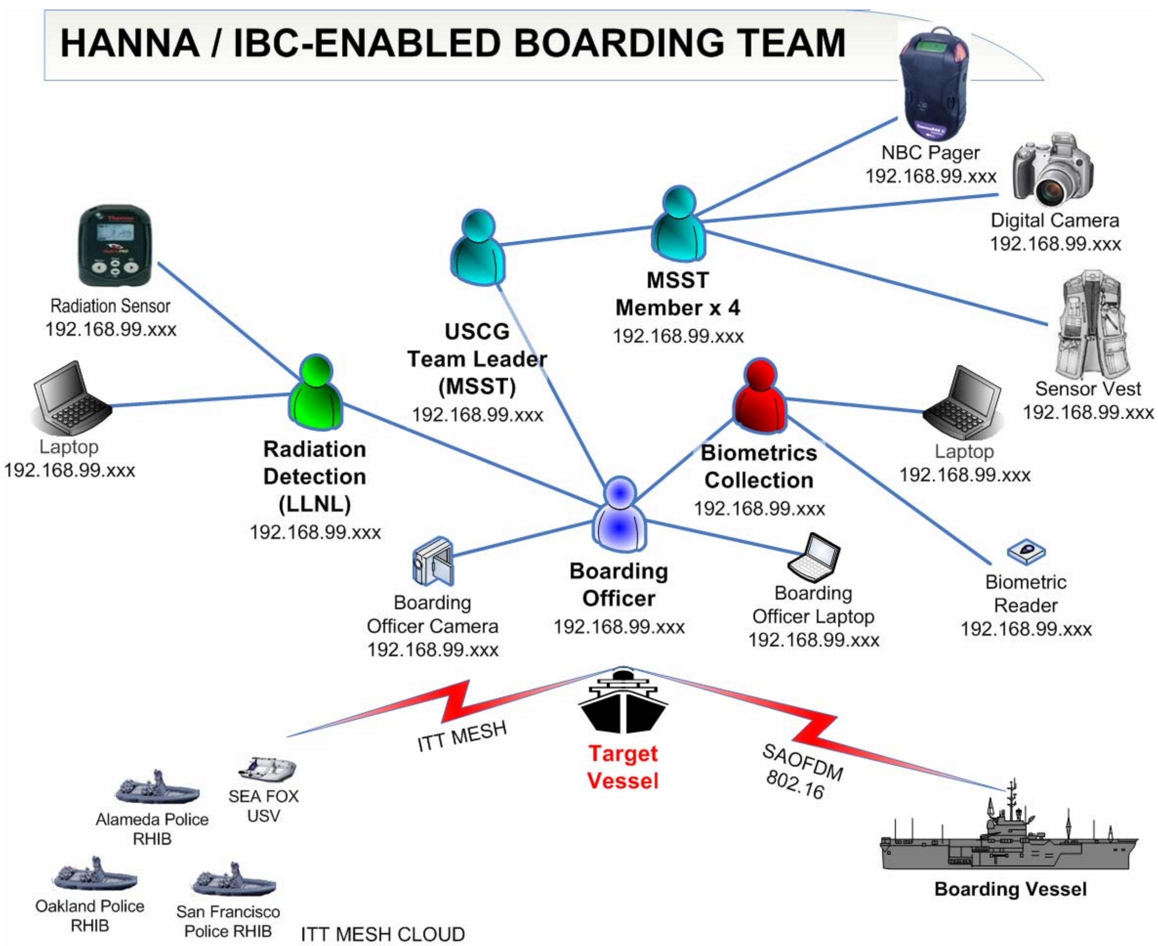

Figure 32. Boarding Officer “HAN” Environment

This diagram represents a utopic vision of what the MIO networking environment might resemble when HANNA-enabled functionality is fully realized. Revealing all HEDs (laptops, radiation sensors, NBC pagers, cameras, vests, and biometric readers) depicts big thinking on paper when in practice, HANNA should start small with two or three HEDs. This will focus evaluation on specific measures of performance and enable experimenters to refine their requirements as HAN technologies mature.

C. APPLYING HANNA ARCHITECTURE TO A MIO SCENARIO

1. Applicability of MIO

As previously mentioned, the quarterly MIO Experiment provides a generous opportunity to iteratively evaluate and develop HANNA's architecture. Each experiment follows a scripted scenario set in a maritime environment consisting of 12 Events. Each event is designed to test a capability or technology that has been integrated into the experimental testbed. The events develop in a manner similar to actual maritime operations, from strategic to tactical levels. The scenario below describes an introductory-level test of HANNA's capabilities by introducing three HEDs into the experiment.

2. Order of Events

Events 0 - 6 do not take place at a scale conducive to testing HANNA; however, they remain valuable because they provide a foundation for subsequent events which could benefit significantly from the use of HANs. In summary, Events 0-6 open with a Headquarters (HQ) Commander promulgating reports of possible terrorist indications and warnings (I&W) on the West Coast. Suspected terrorists could be attempting to smuggle nuclear materials into the U.S. via major marine ports. This information is disseminated from a HQ command to subordinate tactical commands. Subsequently, two vessels conduct search and detection operations eventually leading to positive detection of radiological materials. The detection initiates several actions, including the dispatch of United States Coast Guard (USCG) Maritime Safety and Security Team (MSST) Boarding Parties tasked with gaining access to and searching the target vessels.

In **Event 7** the Boarding Party arrives, boards, and searches the target ship. The Boarding Officer establishes communications with HQ for retrieval of relevant details and transmission of sensor data to the network for analysis and collaboration. The Boarding Parties employ HED radiation pagers to discover radiation signatures on the vessel where ship documents indicate no logical reason for the presence of radiation. During the collection process, the radiation HED transfers radiological data to the Boarding Party member's HANNA.

Following the data collection phase, the radiation collecting Boarding Party team member transfers the relevant information from his HANNA to the Boarding Officer's HANNA through touch. The Boarding Officer uploads the same data to his HED PC through another touch and posts the radiation data in the HQ C^2 workspace.

Event 8 requires Lawrence Livermore National Laboratory (LLNL) reach-back analysts to download the radiological data from the HQ C^2 workspace for analysis.

In **Event 9**, the LLNL reach-back section posts the results of their radiological analysis in the HQ C^2 workspace.

Event 10 permits the HQ Commander to direct the actions of the Boarding Party based on the radiological analysis results posted by LLNL reach-back.

Event 11 finalizes the scenario with the Boarding Party reporting all secure. A local law enforcement Sheriff's Boat dialogs with the HQ Cmdr about departing to proceed on duties assigned, but it may remain in the network.

Event 12 finds the HQ Cmdr requesting plume modeling from LLNL Consequence Analysis. Results are discussed with emergency responders to include evacuation possibilities.

3. Identification of HANNA Functionality in MIO

Figure 33 echoes a representation of the functional loop presented in Chapter III (Figure 23). As a reminder, black, solid arrows indicate the primary, sequential flow of HANNA functions while dotted red arrows specify feedback between adjacent functions. Black, dotted arrows extending from Feedback (F5) represent non-adjacent feedback loops. The validity of this model becomes apparent when discussed in the context of actual use such as how it relates to the MIO scenario. The initial I&W report, mentioned in Events 0 – 6, represents the Decision Support function (F1) annotated in Figure 33. Following this I&W report, several instances of the Tasking function (F2) emerge. A noteworthy result that follows from F1 includes the tasking of MSST Boarding Parties to investigate suspect vessels. After conducting its assessment of the target vessel, the Boarding Party demonstrates the Communication function (F3) by employing HANNA to deliberately, autonomously, and securely pass data to higher level decision-makers. Communications dovetail directly into the Situational Awareness function (F4) when the same higher level decision-makers attain a more refined understanding of the situation based on the information delivered in the communications. LLNL reach-back processes the radiological information and promulgates their product through the Feedback function (F5). Finally, the cycle is completed when the HQ Cmdr applies LLNL reach-back's analysis for Decision Support that results in additional tasking for the Boarding Team.

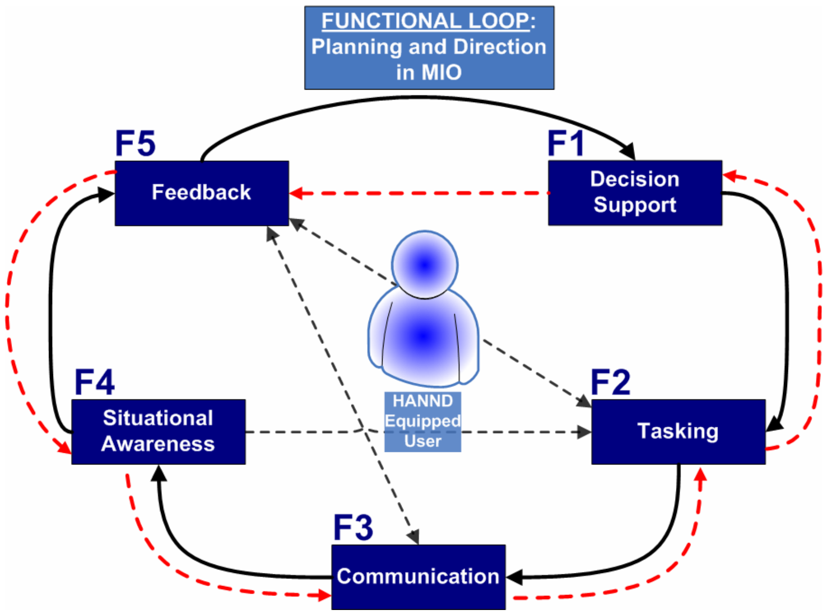

Figure 33. MIO HANNA Function Model.

4. Identification of HANNA Quality Attributes in MIO

An explicit set of functional expectations provides the foundation for developing clear and effective quality attributes for HANNA. The quality attributes of Usability, Interoperability, and Security best envelop the most critical of HANNA's quality attributes as they apply to the MIO exercise. Figures 34, 35, and 36 develop these quality attributes to the 4th level, drawing from MIO scenario excerpts as a demonstration.

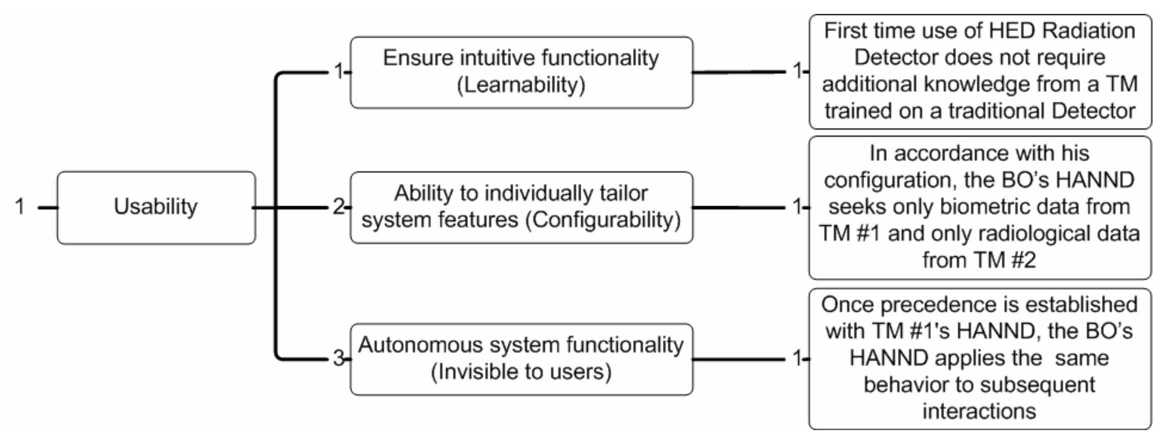

Figure 34. Usability Quality Attribute in the MIO scenario.

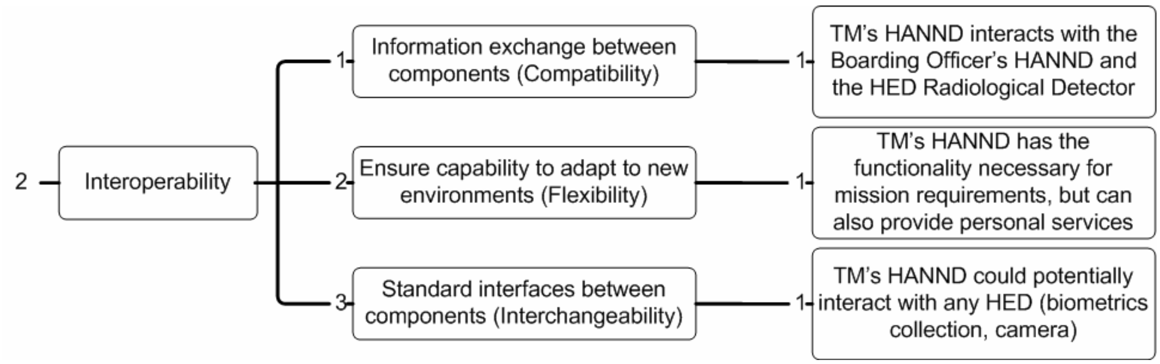

Figure 35. Interoperability Quality Attribute in the MIO scenario.

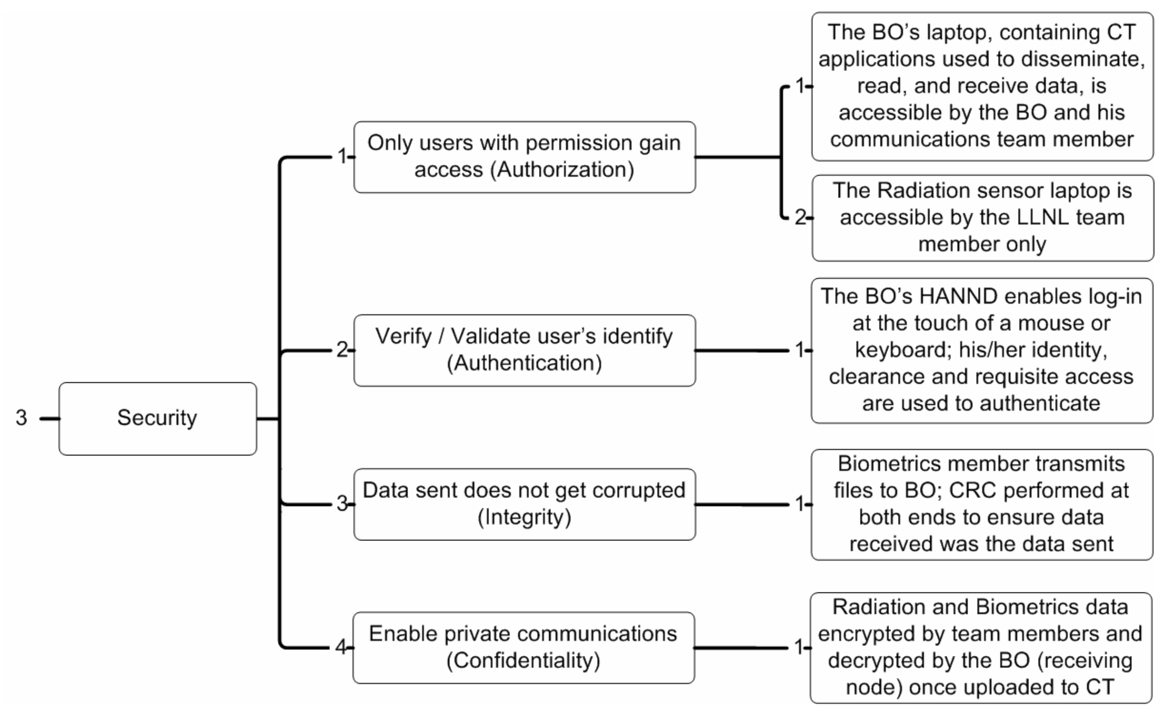

Figure 36. Security Quality Attribute in the MIO scenario.

Defining and applying QAs to a real scenario, like the one above, facilitates the task of measuring QA effectiveness which subsequently contributes to the development of future HANNA components.

D. EVALUATING HANNA IN MIO EXERCISES

1. Measures of Performance

The scenario events above provide the framework for studying measures of performance (MOP), mainly in the area of data transmission between the various actors and sensors depicted in Figure 32. Related MOPs pertinent to future implementations of this HAN include:

- The ability of the boarding party to rapidly connect and efficiently collaborate with internal assets in order to provide biometric, radiation, and photographic data to external subject matter experts via 802.16 or other wireless architectures. This would require an experimenter to:
  - Measure time (in seconds) to connect HEDs using IBC.
  - Measure time (in seconds) to transmit data between HEDs using IBC.
  - Measure throughput, data rate, and latency of connection between HEDs.
- The time saved when Boarding Party members transmit data using HANDs as opposed to “thumb-nets” or “sneaker nets.”
  - Measure time (in seconds) for transferring biometrics data from sensor devices to nodes containing collaborative technology applications.
  - Measure time (in seconds) for transferring radiation data from sensor devices to nodes containing collaborative technology applications.
  - Measure time (in seconds) for transferring photographic data from sensor devices to nodes containing collaborative technology applications.
  - Repeat previous three measurements for transferring data from various sensors using IBC technologies then compare results.
- The time to reach decisions before proceeding to the next step in the process (as it relates to the second MOP).
  - Measure total time (in seconds) saved or lost using “as-is” (thumb-net) versus “to-be” (HAN/IBC) techniques. Time starts at the point of connecting the sensor data device and stops when the Boarding Officer receives decisions via collaborative tools. Efforts to reduce confounding variables should be made, i.e. complexity of decisions and amount of data (number and size of files) should be equitable across the comparison(s).

- The latency of synchronization with remote sites including the time needed to acknowledge and process shared data.
- The ability to establish HANNA communications protocols within the Boarding Team.
    - Measure using Likert-scale surveys focused on 'usability' QA.
- The perceived improvement in SA for Boarding Team members employing HANDs that autonomously detect (TSAS-enabled radiation sensors) and transfer data (IBC, Red Tacton).
    - Measure using Likert-scale surveys (1-5, high to low).

Exploring the option of integrating HANNA into the MIO marks a tremendous improvement over current methods of collecting, processing, and disseminating time-sensitive data. Evaluating time saved in an environment where seconds can separate life and death directly highlights the potential benefits of touch networks. Further, implementing this new technology directly contributes to enhanced situational awareness on the part of the Boarding Team and those with whom they collaborate. This chapter proposed an incremental, evolutionary implementation strategy for integrating HANNA into the existing and future research tasks of the NPS MIO experimentation test-bed. This proposal also included a consideration of the functional and quality attributes, taken from the HANNA architecture, as they related to specific MIO events. This step ensures achieving credible solutions that strive to satisfy end-user requirements. The final chapter of this thesis concludes with an examination of additional academic areas that show promise for helping to bring HANNA to fruition.

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V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

A. THESIS CONCLUSIONS

Chapter I introduced a not-too-distant future military scenario which illustrated several “networking by touch” possibilities aimed at maximizing individual user efficiency and effectiveness. This opened imaginative windows of opportunity in the first two chapters while Chapter III attempted to clarify the critical components and associated architecture necessary to achieve the desired end-state. Credible responses resulted in a definition of a Touch Network Architecture as well as the functional and quality attributes to consider when integrating the components to progressively construct a HANNA. Chapter III also provided the foundation for both of those requirements along with recommendations on how to continue adapting future modifications to rapidly maturing technologies.

While Chapter IV addressed a proposed HANNA implementation within the specific context of MIOs, several other areas warrant additional research in order to effectively integrate, and ensure the longevity of, “Touch Networks” within the DoD Networking Architecture. The following recommendations intend to provide future students with starting points to explore the incremental, evolutionary approach HANNA requires in order for it to achieve realistic success.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Information Sciences, Information Systems Strategy and Policy: Architecture Expansion

Chapter III presented the foundation for HANNA architecture and defined the functional and quality attributes to consider when integrating the components that construct a HANNA, i.e., HANND, HED, software, etc. Continued innovations in technology dictate adjusting the services so that these two might seamlessly co-evolve. This demands immediate, systematic, and cyclic attention in two areas: requirements development and SOA, in that order.

Defining and continuously refining requirements represent a crucial, albeit often neglected, cost savings step in software development. Employing objective methods for fact gathering and analysis will ascertain customers' requirements regarding the desired quality of services. Managing responses to the key, customer-centric questions then provides necessary insights towards developing a SOA and defining the subsequent services it should support. Students seeking to apply HANNA to particular problem sets should first attempt to answer the following questions as set forth by Cummins and Keen:

- Who are your customers, and how do you know?
- Can you demonstrate how you are satisfying your customers?
- How do you get feedback from your customers?
- How are you doing based on that feedback?
- What are your customer's priorities, and how do you know?
- How do you help customers meet their priorities?
- How do you prioritize work to improve customer satisfaction?

(Cummins and Keen 1994, 590)

As requirements crystallize, a SOA might be developed using the Openwings approach which "provides a Service-Oriented Programming framework for dynamic networked systems of software and hardware components" (Openwings). The focus of this approach rests in the components which use and provide discoverable services such that "every component is a manageable, reusable encapsulation of functionality that can be dropped into any context because it is independent of platform, protocol, environment, or database" (Ibid). One possible military scenario might examine the application of a HANNA SOA that facilitates the synchronization of battlefield elements including collection systems that sense, engagement systems that shoot and Command & Control (C^2) nodes which facilitate decision support connecting the previous two. A SOA that tied these human nodes together in a manner capable of delivering credible solutions for integrating and automating the collection, processing, and dissemination of fleeting combat information to decision makers anywhere on the battlefield, represents a small first step with potentially huge returns.

2. Operational Research (OR), Human Systems Integration (HSI): Human Considerations in Implementing HANNA

Human Systems Integration (HSI) represents an interdisciplinary program that emphasizes human considerations as a priority in systems design and acquisition to reduce life cycle costs and improve total system performance. HSI breaks down into several distinct domains that include human factors engineering, manpower, personnel, training, human survivability, health hazards, system safety, and habitability. HSI is based on the understanding that people (operators, maintainers, and support personnel) are critical elements of the system and that a human-centered design perspective promotes system effectiveness, safety, and cost savings (NPS). One potential avenue of research in this area involves exploring how system designers would incorporate HSI ideals into HANNA to develop products that integrate seamlessly and intuitively with their users.

In some regards this thesis seems to present a be-all, end-all solution to pervasive, ubiquitous, networking environments that abolish all existing information glut issues thereby eliminating the need for the human cognitive process. In fact, HANNA doesn't replace thinking; rather, it rapidly augments the process in such a way as to close the divergent gap between linear human cognitive abilities and the exponential growth of technology, i.e., more memory, hard drive space, and processing speed. Dr. Rick Hayes-Roth refers to this focus as "getting 1000 computers to work for Snuffy" (Hayes-Roth, January 10, 2007). HANNA proposes one computer that facilitates seamless interaction between various environmental nodes through deliberate, physical interaction to create, store, and transfer an ever-updating "world model," on our person, wherever we roam. A HSI student could develop a user model for personal agents, and use that model to further develop human considerations integral to the development of subsequent agents, keeping in mind that these agents comprise a window towards achieving Snuffy's 1000 computer workforce.

3. Defense Analysis (DA), Information Operations: Social Networking

The implied social themes of HANNA beseech potential users to leverage the technology for social networking. Consequently, this capability warrants analysis regarding how social networks impact or integrate with HANNA's potential social networking capability. One facet that designers should consider is the ideal group size. Author Malcolm Gladwell's research reveals the work of British anthropologist, Robin Dunbar, who developed an equation which estimated the effective social channel capacity of human networks to consist of approximately 150 people (Gladwell 2000). Coincidentally, this number also describes the approximate size of an infantry company, the smallest stand-alone ground tactical unit.

Joint Information Operations (JIO), a Defense Analysis discipline, educates military personnel and civilian officials in the strategic and operational dimensions of information relative to the use of force as an instrument of statecraft (NPS). Tenants of JIO include developing information strategies to support military action by taking advantage of information technology, exploiting the growing worldwide dependence on automated information systems, and capitalizing on near-real-time global dissemination of information to affect adversary decision cycles with the goal of achieving information superiority (Ibid). JIO studies include military art and operations, the human dimension of warfare (psycho-social), and methods of analyzing military capability. This discipline appears to be steeped in understanding the various aspects of social networking. Students enrolled in this curriculum might explore how to leverage the advantages of HANNA functionality to develop and maximize the effectiveness of social networks. For example, the student might explore potential applications of HANNA functionalities in clandestine operations, and determine the structure of social networks that support such operations.

4. Computer Science, Modeling, Virtual Environments, and Simulation (MOVES), Extensible Markup Language: Developing Schemas (XSL) in Support of HANNA Agents

The essence of HANNA is information exchange. The payload of every touch delivers binary-encoded data to a source. A universal format for all data exchanged represents a key enabler of many of HANNA's quality attributes, specifically, interoperability. Incorporating a data language that supports semantic congruity, like the Extensible Markup Language (XML), directs inherent interoperability of information between devices, services, and multitudinous agents. The primary purpose of XML is to facilitate the sharing of structured data across different information systems. XML's extensibility allows users to define their own specification of the language. Additionally, the XML standard provides functionality for easily translating from one specification to another. XML could potentially construct data files, access databases and spreadsheets, check and validate data values, and output data; all of which fall within the realm of HANNA's capability.

The MOVES curriculum hosts basic and advanced XML courses of study open to students from any curricula. The basic course presents the benefits of XML and how to use software tools to construct and process XML documents using XML editors, XML parsers, XML Schema for validation, Extensible Style sheet Language Transformations (XSLT) to transform documents, and Document Object Model (DOM), Simple Application Programming Interface (API) for XML (SAX), and Java DOM (JDOM) to access and manipulate XML documents within a computer program. The advanced course presents more complex principles and practices for web-based document design and authoring using XML data structures, XML applications, and XML-based languages. A student with this XML background could easily develop an XML schema for HANNA agents and services, bringing the technology one step closer to reality. A logical first step identifies the common elements of all agents and services and defines their data structures first. Built off the inherent interoperability of the data language, a preexisting library of common elements would eliminate redundancy of those common elements in individual agents and services. Subsequently, a student could develop a data language for a particular agent. Building on the common library, the agent would only need a data language specific to its service.

5. Information Sciences, Network Operations Center: Measuring Network Performance of HANDs

The Tactical Network Topology (TNT) test bed, sponsored by NPS, offers additional hands-on opportunities to assess HANs and their associated devices. The TNT test bed is comprised of a unique, globally distributed, plug-and-play network and the business process of high-profile, quarterly experiments, which involve several U.S. Government agencies with the common goal of "identifying breakthrough solutions for emerging unmanned vehicle sensors and self-organizing networks" (Bordetsky 2006). This USSOCOM-NPS experimentation campaign, created by distinguished professor and Director, USSOCOM-NPS Field Experimentation Cooperative, Dr. Dave Netzer, comprises a "unique applied research vehicle and incubator, which facilitates the rapid introduction of prospective commercial networking and information technologies to the market of major DoD and Homeland Security customers" (Ibid). The TNT environment represents an ideal setting to introduce and evaluate innovations such as HANNA at a minimal cost and with low-risk to the government.

Proving the concept of data exchange in field settings using the electrical capacitance of human skin marks the first step towards validating HANNA's functionality outside of pristine laboratory conditions. A robust suite of network monitoring tools employed during TNT offers the ability to capture metrics regarding MOP as they pertain to IBC or other HAN technologies. The multitude of network technologies available for testing provides ample opportunity to evaluate HAN as stand-alone, last tactical yard components; or one could compare its performance relative to existing network paradigms.

Current scenarios require minimal adaptation to incorporate this new technology into the TNT test bed. Mission planning and intra-Network Operations Center (NOC) or Tactical Operations Center (TOC) collaboration present initial footholds which could easily scale to applying HANNA in battlefield medicine or HVT missions. Collecting and disseminating biometric identification data, similar to the MIO scenario in Chapter IV, offer other possibilities to evaluate IBC/HAN. Students following these suggestions should consider how new technologies integrate with current tools to facilitate developing the adaptive, tactical networking management paradigm of “Network-on-Target (NoT)” (Bordetsky and Bourakov 2006). This process requires “new techniques for adaptive remote management of mobile wireless nodes and their rapid remote or autonomous reconfiguration at both physical and application layers, subject to changing operational requirements” (Ibid). Designing the intelligent “agent” aspect of HANNA to provide autonomous, context-specific data transfer through the intuitive act of touch, assists in developing the NoT goal.

6. Information Sciences, Tactical Situational Awareness System

The TSAS aviation variant’s initial success opens the door to expand future experimentation into potentially larger markets, specifically, troops on the ground. Ground combat elements such as Special Operations Forces (SOF) teams (or firefighters on the civilian side) might employ TSAS Ground (TSAS-G) vests to receive intelligent communications pertaining to threat composition, disposition and strength updates, or as navigation aids when operating in unfamiliar terrain. Additionally, SOF teams would employ TSAS-G during complex insertion/extraction operations to mitigate the potential risks of injury and/or compromise. This product variant delivers the most value in environments that saturate our senses to distraction. Take firefighting, for example. Inside of burning structures, the surroundings are loud, hot, chaotic, and visually obscured by thick smoke, all of which tax human sensory capacity and complicate effective communications. Personal safety remains another target area as firefighters typically don’t have building layouts memorized and, due to the unpredictable nature of fire dynamics, can find themselves trapped by deadly flames. Shipboard firefighters retain the advantage of environmental familiarity; however, walls of naval vessels are generally impenetrable and the ship's structural integrity remains their lifeline. Special consideration for the amount of gear carried, relative to different units and various job descriptions should accompany any implementation of the TSAS-G variant.

Students interested in pursuing this extension of Touch Networking should contact Dr. Alex Bordetsky (CENETIX). Potential applications for testing proof of concept and evaluating network measures of performance exist in both the aforementioned MIO and TNT environments.

7. Information Sciences, Business Process Re-engineering and Knowledge Value Added: Alternative "Value" Assessments of HANNA

Knowledge Value Added (KVA) provides a means for organizations to measure the Return on Investment (ROI) of its knowledge-based assets. While KVA may be difficult to measure, its influence on the financial bottom line is certainly discernable. In the business world, profits keep a corporation afloat, but the government's ability to function is not so dependant upon these bottom lines. Although the government may not be concerned with generating revenues, it relies heavily on its knowledge base. Military personnel are all too familiar with the introduction of new and improved processes in the form of new weapon systems, latest versions of computer programs, or revised Standard Operating Procedures (SOP). With each new system introduced, implementation and maintenance requirements necessitate considerable man-hours and an extensive knowledge-base. KVA eschews ROI by comparing as-is (status-quo) with to-be (subsequent to introduction of new technology) solutions by employing unique analytical techniques to articulate the economics of a new technology. Students with interest in this area might use KVA to justify investing government money on the research, development, and adoption of HANNA by demonstrating the orders of magnitude gains in system efficiency. Additionally, students could explore how much HANNA improves functionality through the automation of mundane processes.

Recall the mathematical computations on page one of this thesis and the notion of ever-increasing amounts of information that followed in Chapter II. At 150 pages with a T-1 connection, the content of this document would download to your computer in less than one second. Consider how long it took to read those pages. Then consider how long it could take HANNA to concisely convey the elements of relevant knowledge to you, the reader. HANNA's value, as a future investment to DoD knowledge based decision support systems for example, should be developed, evaluated, and implemented in precisely this manner.

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APPENDIX A. GLOSSARY OF TERMS

802.11 - The Institute of Electrical and Electronics Engineers standard for wireless local area network interoperability.

Agent - A piece of code with some autonomy and purpose *(also Intelligent Agent).*

Appliance - An appliance or “network appliance” is a term used to denote a relatively low-cost PC designed for network access and specialized business use.

Application - A program that is self-contained and that executes a set of well-defined tasks under user control.

Architecture - In terms of data processing or information technology, a general term for the structure of all parts of a computer system (hardware and software).

Authentication -The process of verifying that a person is who he or she claims to be.

Authentication, Authorization, and Accounting - A framework for intelligently controlling access to computer resources, enforcing policies, auditing usage, and providing the information necessary to bill for services. These combined processes are considered important for effective network management and security.

Authorization - The process of allowing system access to a person.

Backbone – The top level of a hierarchical network; major pathway within a network offering the highest possible speed and connecting all major nodes. The main pipes along which data is transferred.

Bandwidth – The maximum amount of information that can be sent through a connection at a given time (usually measured in bits per second (bps)).

Biometrics – The science and technology of measuring and statistically analyzing biological data.

Bits Per Second (BPS) – A unit for measuring the data transmission rate, for example, the transmission path of a modem.

Bluetooth – Bluetooth consortium introduced open Bluetooth 1.0 in 1999 developed for economical, short-range, wireless links between PDAs, laptops, cellular phones, and other (mobile) devices. Bluetooth devices are capable of detecting each other automatically and setting up a network connection. Using a modulation frequency of 2.4 GHz, data is transferred from one adapter to another, whereby the signals do not have a predefined direction and can, in principle, be received from any other device. The first hardware and software products equipped with Bluetooth were introduced at the end of 1999. By 2005, 700 million devices were in use.

Browser – Client application that is able to display various kinds of Internet resources.

Byte – There are eight bits per byte, which is used to represent a single ASCII character, for example.

Chip – Term for complex, integrated circuits that can contain several hundred thousand semi-conductor circuits (transistors or diodes, for example). By creating structures as small as one thousandth of a millimeter, higher levels of integration can be achieved.

Client – Application that resides on the customer's computer and contacts a server to communicate, such as IRC clients or Web clients.

Client/Server – Databases in a network are often administered from a central location by a server. Client software installed on the user's computer retrieves required data from the server.

Cognitive Complexity - A measure of the demands made on the user's cognitive system, in terms of complexity of information presented to the user in the interface, complexity of layout, demands made on short-term (working) memory, variability of the interface, pace of interaction, etc. This is one of the most important criteria measured in a usability test.

Content - Information that has a tangible aspect because it has been collected and contained in a content object. Content can be unstructured (usually text) or structured (database). Content can be collected at differing levels of granularity.

Context of Use - A description of the actual conditions of which the system is under assessment, or will be used in a normal day-to-day working situation. Examples of conditions include: the users, tasks, equipment, and the physical, social, and organizational environments in which the system is used.

Database - A term with several meanings: refers to a DMBS (Database Management System) as well as a file that contains, for example, customer addresses or other data. A database can combine several tables into one file. Often, only one table is allowed per database file for PC databases. In this case, the user can still create a link to other tables from various files.

Data Rate - Also known as data transfer rate. Indicates the number of data units per specified time internal in bps (bits per second).

Decision Support Systems - A class of computer-based information systems including knowledge based systems that support decision making activities; an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making.

Device - A machine designed for a purpose. In a general context, a computer can be considered a device.

Download - Information or programs can be copied from a server to the computer's hard disk or other data media. Common examples of downloaded data include drivers for hardware components or updates for software applications.

Essential Task - Those specified and implied tasks which define mission success. Take the previous two lists and select those tasks which absolutely must be accomplished in order to declare the experiment a success.

Familiarity - Degree of correlation between the user's existing knowledge and the knowledge required for effective interaction with a system.

Field - The smallest unit in a record in a database. Each field has a specific data type that contains, for example, text, dates, currencies, etc.

Gigabits Per Second (Gbps) - Billions of bits per second. Gbps represent a new frontier of telecommunications possible through fiber optics.

Gigabyte (GB) - 1024 Megabytes, often rounded to 1000 Megabytes for easier calculations.

Global Positioning System (GPS) - Series of 24 geosynchronous satellites that continuously transmit their position; used for personal tracking, navigation, and automatic vehicle location technologies.

Global System for Mobile Computing (GSM) - A digital mobile telephone system that is widely used in Europe and other regions. GSM employs a variation of time division multiple access (TDMA).

Graphical User Interface (GUI) – Allows users to navigate and interact with information on their computer screen either through the use of a mouse or by touch to drag data around the screen, instead of typing words and phrases.

Haptic Interface - Of or relating to or proceeding from the sense of touch; "Haptic data"; "a tactile reflex"

Human-Computer Interaction (HCI) - A discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them including software and hardware.

Implied Task - Tasks not necessarily written or spoken but still necessary in order to accomplish the overall mission (usually in support of specified tasks). Analysis of "reading between the lines" usually reveals Implied Tasks.

Information - the result of processing, manipulating and organizing data in a way that adds to the knowledge of the receiver. In other words, it is the context in which data is taken.

Intelligent Agent – A responsibility-accepting performer to whom you delegate and from whom you get desired results or exception reporting, usually possessing context, task knowledge, and knowledge-based means to bring about desired results under given constraints, e.g., an application that helps a customer by completing transactions, seeking information or prices, or communicating with other agents and customers.

Intelligent Appliance - Any type of equipment, instrument or machine that has its own computing capability; a device that uses intelligence agents to perform the work that needs to be done.

Internet Service Provider (ISP) - A company that provides individuals, and other companies, access to the Internet and other related services such as personal mail boxes. ISP's have the equipment and telecommunication line access required to have points-of-presence on the Internet for the geographic area served.

Intra Body Communication - Information imparted, interchanged, or transmitted in which the human body is the transmission medium

Joint Photographic Experts Group (JPEG) - One of the most popular graphic formats. The JPEG format frequently used in digital photography compresses large or color-intensive pictures to a fraction of their original size. This reduces storage requirements and file transfer time.

Kilobits Per Second (Kbps) - Thousands of bps. 9600 bps may thus be expressed as 9.6 Kbps (pronounced "nine dot six"). The rate of 56 Kbps can handle most types of data efficiently and at lower costs.

Knowledge - Formally defined as: Facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject. Knowledge acquisition involves complex cognitive processes: perception, learning, communication, association, and reasoning. The term knowledge is also used to mean the confident understanding of a subject, potentially with the ability to use it for a specific purpose.

Knowledge-Driven DSS – provides specialized problem solving expertise stored as facts, rules, procedures, or in similar structures. The expertise consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems.

Knowledge Management - Discipline of gathering, organizing, managing, and disseminating a corporation's structured and unstructured information resources in order to improve decision making and maximize staff productivity.

Local Area Network (LAN) - Computer network limited to a certain location.

Locality of Reference - Computer communication follows two distinct patterns: (1) A computer is more likely to communicate with computers that are physically nearby than with computers that are far away; (2) A computer is more likely to communicate with the same set of computers repeatedly.

Me-centric - Approach in computing that puts the human needs in the focus of the design. Instead of creating tools that help people doing their tasks, me-centric computing does the tasks on behalf of the people Hayes-Roth, *Radical Simplicity*).

Megabits Per Second (Mbps) – Millions of bps. The T1 link (standard communications offering from most providers) has a total capacity of 1.544 Mbps, typically shared among users in 56 Kbps channels. Broadband communications uses high-frequency transmission to send large volumes of traffic over long distances.

Megabyte (MB) - 1024 Kilobytes (or 1000 Kilobytes).

Metadata - Assigned information "tags" or key words that help index documents or resources by providing background information such as: creation date, authors, date of last update, etc. Metadata is not necessarily visible to the user, but rather works in the background to ensure that documents are properly indexed for searching. It can be stored in the fields of a document itself or in a relational database.

Mission Analysis - The purpose is to carefully evaluate the tasks, in light of the situation, in order to ensure complete understanding of what the unit intends to accomplish. This understanding and awareness of the mission and information relating to it is paramount for planners and participants in key leadership positions. These members review/analyze the purpose, end-state, guidance and other [pertinent] information provided by various sponsors and participants. The final goal is to produce a commonly understood, universally accepted Mission Statement.

Modulator/Demodulator (Modem) - Device between computer and phone line that converts computer signals to a form that can be used to transport data over telephone networks.

Multi-Mode Interface - Use of multiple modes, such as voice and images, at the same time, to communicate with the user. For example, vehicle navigation systems provide maps of routes combined with a voice that indicates upcoming turns along that route.

Network - The connection of two or more computers in order to share resources.

Operating System (OS) - Software loaded right after the boot time; provides the basic functionality to run applications based on a single set of instructions. An OS manages the resources and processes, input/output controls, file system, and user interface.

Packet – The smallest unit for transmitting data over the Internet. Data is broken up into packets, sent over networks, and reassembled at the other end.

Perception - The process of becoming aware of objects by way of the sense organs; the active process of selecting, organizing, and interpreting the information brought to the brain by the senses (see also Sensation).

Permission – The ability to access (read, write, execute, traverse, etc) a file, directory, service, or agent. Privileges carry particular importance as humans interact with more appliances that require different types of information and services which are automatically pulled, given the right permissions.

Process - The sequence of activities, people, and systems involved in carrying out some business or achieving some desired result.

Proof of Concept – A prototype that shows that something can be implemented, but is not necessarily robust enough for a usable system. The difference between a proof of concept and its more complete incarnation is context-dependent.

Prototype - An experimental design of the whole or part of a product used for illustration or testing purposes.

Quality of Service - The idea that transmission rates, error rates, and other characteristics can be measured, improved and, to some extent, guaranteed in advance.

Requirements Analysis - The investigation of a problem that focuses on what functionality is required but not on how to provide that functionality.

Scenario - A narrative describing one or more user's interactions with a computer, including information about goals, expectations, actions and reactions.

Sensation - The passive process of bringing information from the outside world into the body and to the brain. The process is passive in the sense that we do not have to be consciously engaging in a "sensing" process.

Server - A device that provides one or more services to several clients over a network.

Short Message Service (SMS) - A feature of GSM phones that allows users to receive and sometimes transmit short text messages using their wireless phones.

Specified Task - Written tasks that direct what must be accomplished.

Synchronization – Update of two systems to the same level, often required for mobile devices that have been disconnected for a while.

Task - A basic unit of programming that an operating system controls. Depending on how the operating system defines a task in its design, this unit of programming may be an entire program or each successive invocation of a program.

Transaction - Ensures that any modification to a database is carried out either completely (i.e., all records) or not at all.

Transmission Control Protocol/Internet Protocol (TCP/IP) - A set of protocols that are the foundation of the Internet and that enable the communication between computers; technical basis for transmitting data on the Internet. It divides the contents of a Web page into small packets and sends them along different paths, if necessary, to the receiver where TCP/IP then reassembles the packets in their original order.

Usability - The broad discipline of applying scientific principles to ensure that the system designed is easy to learn, easy to use, easy to remember, error tolerant, and subjectively pleasing. A figure of merit or qualitative judgment of ease of use or learning.

Voice over Internet Protocol (VoIP) - A term used in IP telephony for a set of facilities for managing the delivery of voice information using Internet Protocol.

Wide Area Network (WAN) - A network that is distributed over several locations.

Wireless - Using the radio-frequency spectrum for transmitting and receiving voice, data, and video signals for communications.

Wireless LAN (WLAN) - Local area network using wireless transmissions, such as radio or infrared instead of phone lines or fiber-optic cable to connect data devices.

WiFi - Originally a brand licensed by the WiFi Alliance to describe the embedded technology of wireless local area networks (WLAN) based on the IEEE 802.11 standard. Today, it describes the generic wireless interface of mobile computing devices, such as laptops in LANs.

Worldwide Interoperability for Microwave Access (WiMax) - A telecommunications technology aimed at providing wireless data over long distances in a variety of ways, from point-to-point links to full mobile cellular type access. It is based on the IEEE 802.16 standard (also called Wireless MAN). WiMax allows users to browse the Internet on a laptop computer without physically connecting the laptop to a wall jack.

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