Modular Multifunction Information Transfer System (MMITS)

MMITS FORUM

TECHNICAL REPORT #1

Architecture and Elements of Software Defined Radio Systems as Related to Standards

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Printed June, 1997

1.0 Introduction

What is the MMITS Forum?

The MMITS Forum is an open, non-profit corporation dedicated to supporting the development, deployment, and use of open architectures for advanced wireless systems.

Primary objectives of the Forum are:

- to enable seamless integration of capabilities across diverse networks, in an environment of multiple standards and solutions,
- to accelerate proliferation of software-definable radio systems,
- to advance adoption of open architectures for wireless systems,
- to promote "multiple capability and multiple mission" system flexibility, and
- to ensure accommodation of current and future user needs in the areas of voice, data, messaging, image, multimedia, etc.

Current Forum membership comprises an international mix of business and technical decision makers, planners, policy makers, and program managers from a broad range of organizations sharing a common view of advanced wireless networking systems evolution, including:

- Service Providers,
- Equipment Manufacturers,
- Component Manufacturers / Providers,
- Hardware and Software Developers,
- System Integrators,
- Government and Military,
- Standards Development Organizations,
- Industry Associations/Forums, and
- Academic and Research Organizations.

The MMITS Forum Charter presented in Appendix A, delineates the vision, definition, and mission of the organization.

Additional information on the makeup, goals, benefits, and work plan of the MMITS Forum can be found in a companion document, MMITS FORUM PROSPECTUS Version 1.0 6/13/97 available under separate cover from the MMITS Forum.

Standards Requirements/Recommendations Approach

The MMITS Forum is pursuing its goals through the efforts of two core committees, the Markets Committee and the Technical Committee. The Markets Committee is chartered with promoting Forum activities and development of MMITS-concept-based market forecast material. The

Technical Committee is chartered with specifications development. In addition, a Regulatory Advisory Committee is chartered with tracking and coordination concerning regulations relevant to MMITS-concept-based system and product deployment.

The Forum seeks global harmonization of MMITS concepts. Efforts are being coordinated with international industry associations, forums, and standards development organizations (SDOs). The Forum operates under a requirements, rather than technology-driven philosophy, although it is understood that the two areas must be considered jointly. Two broad categories of wireless issues, generally defined as end-user need and technical concern, are recognized. Software-definable radios (SDRs), which utilize conventional and innovative approaches to high-speed digital processing, are the underlying technology holding promise for addressing both issues.

The basic process followed by the Forum is to translate the end-user need into standards requirements/recommendations for action by SDOs. If the Forum is unable to identify an SDO for ownership of the issue, the Forum will develop standards recommendations for release to the industry.
Figure 1.0-1 shows the basic process flow.

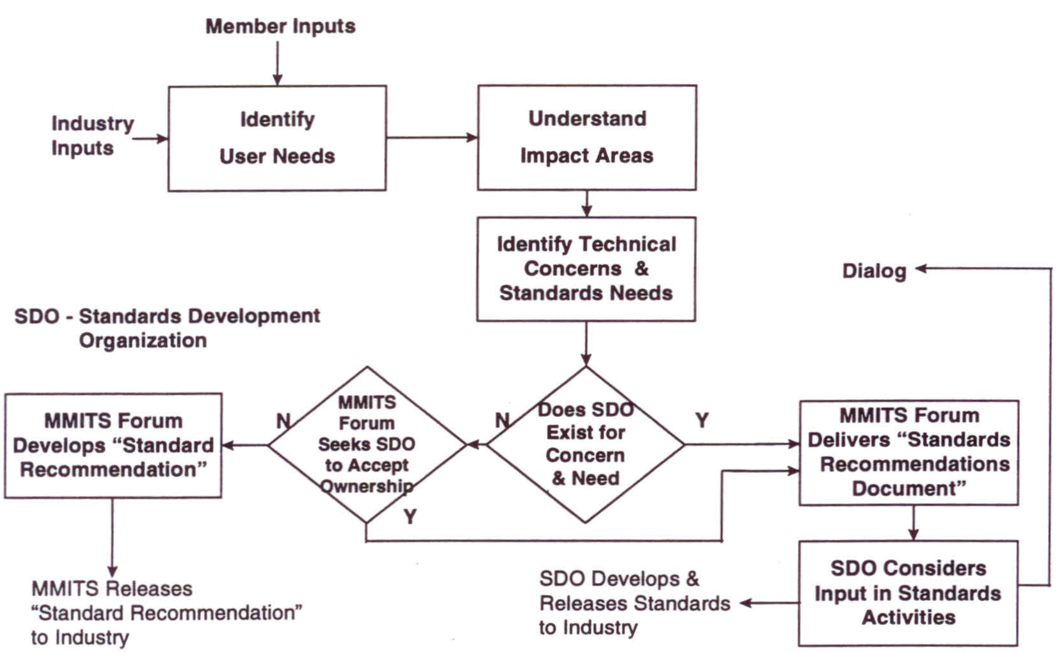


Figure 1.0-1 MMITS Forum Standards Development Process Flow

Structure of this Document

Section 2 (Services and Applications) builds the background, top level conceptual descriptions, and functional requirements that form the basis for these standards requirements/

recommendations. Key to this approach is the modularization of the functions that reflect a balance between a coarse division of functional modularity that may be too general to achieve an open architecture and too granular a specification where every function is described.

Section 3 (Architecture) develops the general reference model for the MMITS architecture. The primary functional modules are the RF section, the modem, antenna, infosec, I/O, environment adaptation, and control. These functional modules may be interconnected to collectively function as a whole wireless unit. The standards requirements/recommendations that follow, take the form of specific requirements for the interface between functional modules and a description of the transfer characteristics of each module.

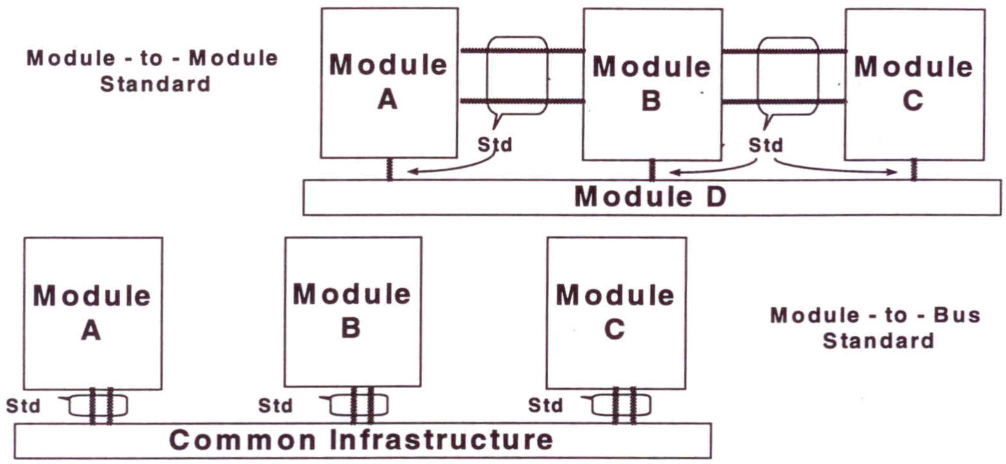


Figure 1.0-2 Generic Representation of Functional Modular Level Standardization

Figure 1.0-2 is a generic representation of a functional modular level standardization approach. The solution may either take the form of a module-to-module (hardware or software) interface, or a module-to-bus standard. The goal is to provide a common interface between modules without restricting and inhibiting the innovation that can be achieved within them. It is necessary that mandatory functions be provided and interface requirements met.

Section 3 also describes the interfaces for a module, separated into an information interface and a control interface. In both cases, these interfaces are bi-directional in nature. There is a separate standard for each of these two interfaces. An interface matrix, developed in a later section of this report identifies the modules and module-to-module elements that require some level of description or standardization. The modules themselves require a description of the functionality that must take place within that module but without specifying what methodology or technology must be used to accomplish it as long as there is compliance with the interface requirements. The module-to-module interfaces will require a standard format for the exchange of information as well as a standard format for the exchange of control.

Section 4 addresses form factor.

Section 5 addresses standards requirements/recommendations for software programmable, open architecture wireless hardware modules and application programming interfaces (API's). Preparing standards for the individual interfaces shown in Table 1.0-1 is much more complex than it appears. The intent of the MMITS is to specify an open architecture that will allow and support a wide range of services and protocols. As part of this effort, existing standards that require some extension to allow software programmable wireless modules to achieve full multi-band, multi-mode operation will be identified.

Table 1.0-1. An Overview of MMITS Role

Standards Requirement / Recommendation Type	MMITS Role
Air Interface	Support identified standards through common architectural partitioning, Identify extensions to accommodate new MMITS capabilities
Internetworking	Support identified standards through common architectural partitioning, Identify extensions to accommodate MMITS capabilities
API	Define
Physical Interfaces	Select from existing open standards
Analog/RF Interconnects	Identify applicable standards and approaches and develop standards recommendations as appropriate
User Interface	None

MMITS will develop selected standards requirements/recommendations for software programmable wireless systems functional modules.

Figure 1.0-3 shows domestic and international private services, the mobile military systems, and civil government and aviation systems. It is the goal of this Forum to specify the module interfaces so they reflect the ability to be configurable and adaptable to many of these varied services.

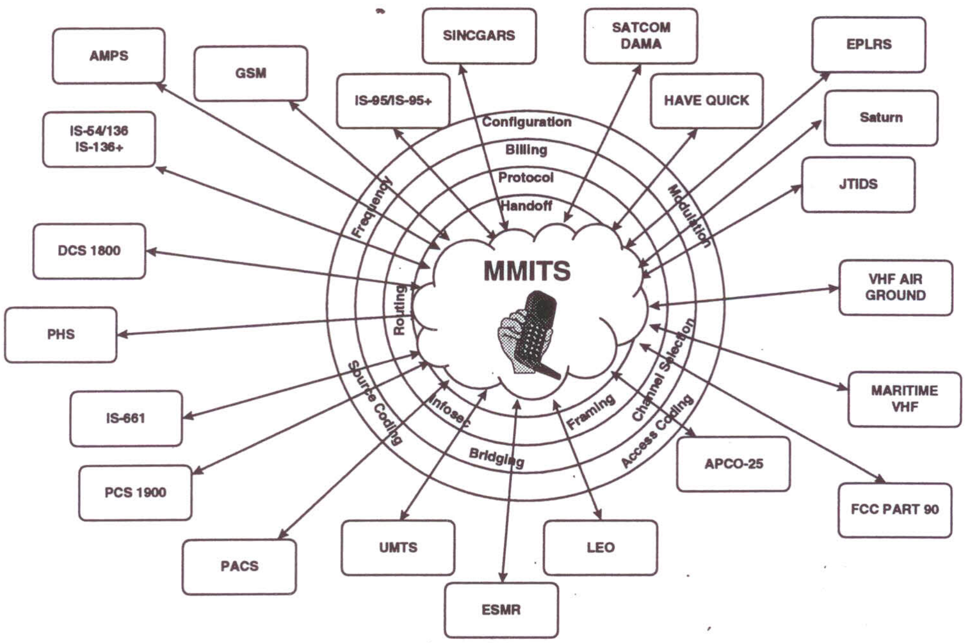


Figure 1.0-3 Some Representative Services for Consideration for Inclusion in MMITS Open Architecture

2.0 Services and Applications

This section reviews the typical usage application environments that provide the background for the technical analysis and standards recommendations that follow. In order to understand the scope and limits of MMITS Forum standards recommendations focus, system context diagrams are presented that depict this information. The type of technical parameters that must be addressed when developing architectures are presented in the service parameter tables.

General Commercial User's Problem

An example of a user's problem follows. I'm late for a meeting. I grab my brief case and... Hold it. What will I need to do on my way to the meeting? At the meeting? After the meeting? Will I need to talk to someone on my cellular phone? Will someone call me on my PCS phone? Will someone send me a cellular fax? Will I get a call on my wireless PBX? Am I expecting a page? Wireless E-Mail? Will I need Web access during the meeting? Does someone need to get in touch with me on the corporate wireless LAN? Will I need to get emergency information from others while I am in the meeting? Where are they? What networks are they on? How will I get to them? I'm trying to save money on air time charges, I will use the wireless LAN system when I am in the building and my cellular system when I am in the car, but what do I do in the parking lot?

To help understand the range of applications that face MMITS, it is useful to look at some examples of problems faced by the various wireless communications users and suppliers in order to provide the motivation for a universal, software defined device to allow seamless use of a range of services.

Commercial Carrier's Problem

The general commercial problem is the need to integrate service portfolios. Carriers with multiple service types and multiple standards want to be able to integrate their service portfolio. Carriers with a single service, single technology strategy fear "bet the business technology decisions" and are being forced into multiple service portfolios by 1) Mergers and acquisitions, 2) International operations, and 3) International roaming. Similar problems exist in the Far East. In addition, in Europe and Japan, capacity problems are creating the need for multimode, multiband solutions.

North American PCS carriers have a unique historical problem, 1)PCS carriers cannot provide coverage in their own license areas initially, therefore, they must rely on AMPS for fill-in , 2) To provide nationwide roaming, PCS must have handsets for a wide range of PCS and cellular standards, and 3) High volume PCS sign-ups depend on the availability of a single device that allows shrink wrap type distribution.

Civil Government's Problem

There is a need for emergency service agencies and law enforcement agencies to intercommunicate. Currently, city, state, and national agencies supporting a national emergency have multiple services and system that cannot intercommunicate readily. Interagency communications usually requires an exchange of assets to support these temporary situations. Likewise, civil aviation requires a wide variety of communications and information transfer to support safe air travel and airport management. The civil aviation authorities would like to be able to upgrade systems in the field as new air interfaces, etc. are developed. This fosters the need for long life cycles of systems as well as "future proofing" to facilitate the expansion of the systems to take advantage of new technologies as they become available and at a reasonable cost for upgrading. The need for reducing the number and types of devices by utilizing adaptive technologies also exists.

Military's Problem

The different branches of the military, each with its own service, need to intercommunicate in a transparent way to realize the implementation of the future electronic battlefield. Currently, information transfer and communication compatibility between services is very limited. Economies can be realized in the reduction of radio procurement programs. (Currently there are more than 200 defense radio procurement programs.) The integration of information and communication systems could result in significant increases in the battlefield efficiencies, the reduction of unnecessary personnel, and reduced budgets.

In addition, there is a need to communicate through public service infrastructures given the current geopolitical situations where the military could be required to operate in any foreign location in a time efficient way. The ability to mobilize and establish a communication environment requires that existing public services be utilized in a time expedient manner.

Manufacturers' Problem

Manufacturers are seeking ways to improve time to market, increase flexibility to add new services and features, reduce the number of fundamental designs, increase the production volume per design, simplify testing, and allow for upgradeability in the field. The flexibility associated with software defined radios and well structured interfaces that anticipate interface features required for new applications overlaid onto existing services, allow the equipment vendor to support customer feature requests for equipment that is already fielded. A reduced number of fundamental designs allows the production volume of each fundamental design to be higher, allows larger component volume purchases, and therefore leads to more cost effective production techniques, and allows insertion of new features during production. Simplified testing/validation arises with fewer designs which must be validated.

Regulatory Agency's Problem

The most pressing regulatory issue is how to meet the demand from the communications industry for additional spectrum that is currently unavailable. The governments of the industrialized nations in general have established regulatory agencies to manage the electromagnetic spectrum. They accomplish this task through rule-making proceedings that classify services, provide RF spectrum for various types of communications links, and specify technical parameters for operation. Historically, as communications needs increase, the need for additional spectrum has been met by opening up new bands at higher and higher frequencies as technology is developed to utilize these higher bands.

Today, this concept is no longer applicable because rapid industrial growth has generated an overwhelming demand for new communications services. This demand has resulted in several stop-gap techniques that have been employed by the regulatory community.For example, in the United States, techniques such as reassignment of government frequencies to the civilian sector, splitting frequency channels in half (FCC refarming docket), interspersing land mobile channels into unused television broadcast channels, etc., have been used. Each of these techniques carries a price tag; depleting government frequencies will likely create future insufficient spectrum capacity for their use, refarming has resulted in compatibility problems between older equipment and the newer technology used to access the additional channels, and interspersing has resulted in increased interference to public broadcast services.

In order to provide for the increasing demand for communications services, current spectrum management policy has been geared to auction spectrum licenses to the extent possible. Tied to this policy is the concept of minimal in-band technical requirements that allows the license holder complete freedom to utilize the most flexible and best technology available to maximize the communications links at his disposal. This regulatory policy is designed to generate a favorable climate for technology development that maximizes the communications link/dollar cost formula resulting in increased efficiency of spectrum utilization.

In summary, the most critical issue for regulatory agencies in the industrialized nations is to develop policies that increase the efficiency of spectrum usage (while reducing mutual interference and increasing the ease of frequency refarming) due to the lack of available spectrum for communications purposes. The only way to meet the ever increasing demand for communications links is through technology breakthroughs that can economically increase the efficiency of spectrum utilization. These breakthroughs are likely to occur through reconfigurable radios that maintain electromagnetic compatibility with existing systems, permit frequency reuse and allow flexibility for future technology upgrades.

Semiconductor Vendor's Problem

As semiconductor vendors view the silicon chip opportunity space, the one thing evident to all players in the market is the question, "how will we keep our fabrications facility full." Coupled with this question is the subtle paradigm change in the industry. So far, it is claimed that it has been silicon chip development driven by the requirements of the systems. The silicon chip was viewed as a way to lower cost, to enhance further integration, and to drive products into new markets. In the current era, as less than 0.25 micron process technologies become commonplace, the paradigm is "systems because of silicon chips" Systems that were considered inconceivable two years ago are now commercial, single-chip products today.

These two issues together are putting tremendous business pressures on semiconductor vendors. To keep fabrications full, they focus on industries which require very large silicon chip volumes. As can be expected, the wireless industry is the focus of almost every major semiconductor vendor for this reason alone. The wireless industry offers tremendous volumes, and increasing digital CMOS silicon chip content in the forms of DSP and microprocessor cores coupled with embedded logic. This picture simply whets the appetite of every silicon chip vendor hungry to move high-margin CMOS silicon wafers. Moreover, the profit margins per wafer are becoming more and more important. This value is derived from the intellectual property in the form of hardware and software.

Playing directly against this is the fact that to succeed in the wireless industry, and recognize the full advantage of the "volumes of silicon chips,"semiconductor vendors must be able to offer silicon chip solutions that support the multitude of standards across different consumer markets and geographical regions. These solutions must appear on the market at particular power, performance, and price points dictated by the end-product market dynamics. This requires the semiconductor vendor to develop application-specific signal processing solutions for every standard, ranging across IS-136, GSM, DECT, PHS, PDC, IS-95 CDMA, and ISM-band cordless systems. This is an expensive proposition today. The cost is dominated by the need to create a customized semiconductor solutions from scratch for every standard. Moreover, this fixed cost creates a limit on the number of design starts that the vendor can support, irrespective of fabrication facility capacity.

The availability of a software-defined transceiver can fundamentally change this design problem, and, as a result, the business equation. The ability to reduce time on the "design start" process, reduce the number of fundamental designs, significantly reduce silicon manufacturing and test costs, and significantly increase the wafer production volumes per design start creates a business environment where semiconductor vendors can address multiple standards in an economically feasible manner. It is recognized that software-configurability will be a key enabler for this capability.

2.1 Context Diagrams

Context diagrams are used here to define the elements of the communication system network that the MMITS-compliant radio is part of and the interfaces of the MMITS-compliant radio to other elements of the system. Context diagrams provide a graphical method to define the scope of what communication system elements that this document addresses. This section will provide context diagrams for representative systems of the market segments: Commercial, Civil Government, and Defense.

Commercial wireless markets are growing rapidly and includes services such as cellular, personal communications services (PCS), paging, wireless data services (e.g., packet radio), cordless phones, wireless local area networks (LANs), satellite, etc. Users value integrated operations in combinations such as cellular, paging, wireless data, and even cordless. Within services, multiple standards exist. The current proliferation of incompatible digital cellular and PCS standards is creating a market environment that will demand software radio technology and standards to facilitate roaming. Figure 2.1-1 provides a representative context diagram for commercial cellular systems.

It is recognized that software-defined radio in the MMITS context goes beyond the bounds of a traditional radio and extends from the radio terminal of the subscriber or user, through and beyond the network infrastructures and supporting subsystems and systems. The focus of the MMITS activity summarized in this report addresses the architecture and elements within the shaded area in the context diagrams. Consideration must also be given to impacts on other elements in the network context diagrams.

Civil wireless encompasses aviation, law enforcement, emergency preparedness, and related applications. These applications address air traffic control and dispatch operations. They are legacy wireless services representing years of operation and installed systems infrastructure equipment. The commercial aviation industry has identified needs for more voice channels and an expansion to include data capability. The traditional 25 kHz channel spacing in Europe is evolving to 8.33 kHz. An international standard for a VHF Digital Data Link (VDL) is currently near finalization. The navigation system is evolving to include the Global Positioning System (GPS). The General Aviation community will maintain legacy radios and systems for years and must be supported.

The public safety, emergency preparedness, and related applications are evolving from 25/30 kHz channel spacing to equipment that supports narrow channel spacing and more channels. Digital operations are envisioned. Interoperation among various agencies and services has usually not been possible and is an identified priority. Civil wireless users desire wireless equipment that supports deployed legacy and more capable emerging radio technologies that software radio technologies can provide. Figure 2.1-2 is a context diagram for a representative civil aviation system.

Current military wireless communication strategies envision integrated operations of land, sea, and air. Highly mobile operation is envisioned with integrated wireless communications extending to even the individual soldiers. Spread spectrum modulation will be employed for multiple access, and low probability of intercept (LPI) or detection (LPD) and jamming immunity and also addresses the multipath fading impairments. Additionally, the typical fixed network infrastructure may be non-existent, thereby necessitating the deployment of transportable and/or highly mobile networks into the field. Thus adaptive network (re)configurations will be required. Multimedia data consisting of data, voice, graphics, and video will be widely available, even in a time varying limited manner to the foot soldier. The goal will be to provide rapid data collection and dissemination in anticipated limited war scenarios within urban areas, mountainous areas, and other geographically restricted areas. Integrated operations will be facilitated by advanced emerging spread spectrum technologies and by flexible software radio that can interoperate with most varieties of narrowband legacy wireless waveforms and equipment. The context diagram for a representative military wireless system is presented in Figure 2.1-3.

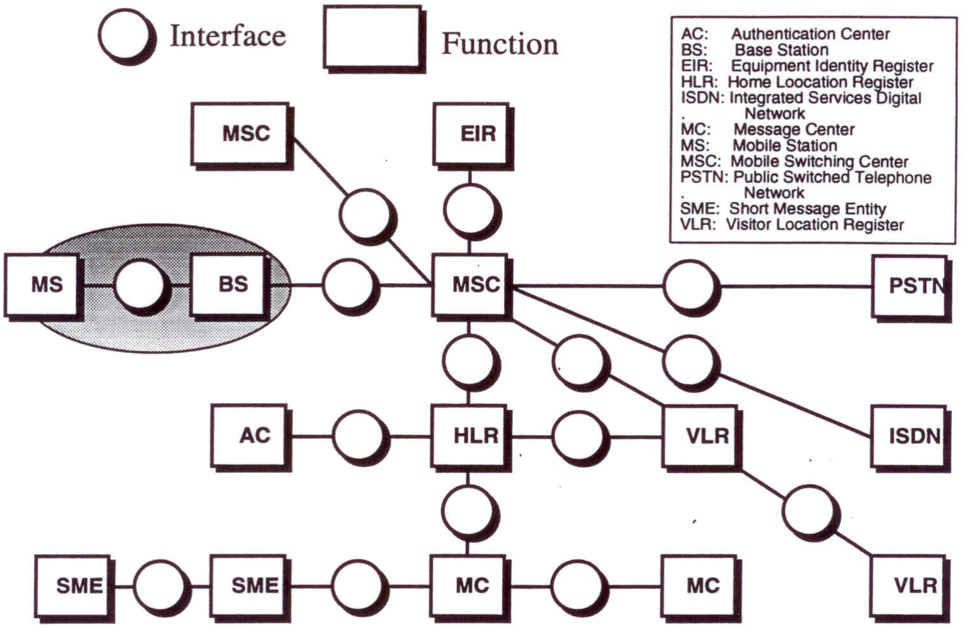


Figure 2.1-1 Network Context Diagram: Cellular/PCS

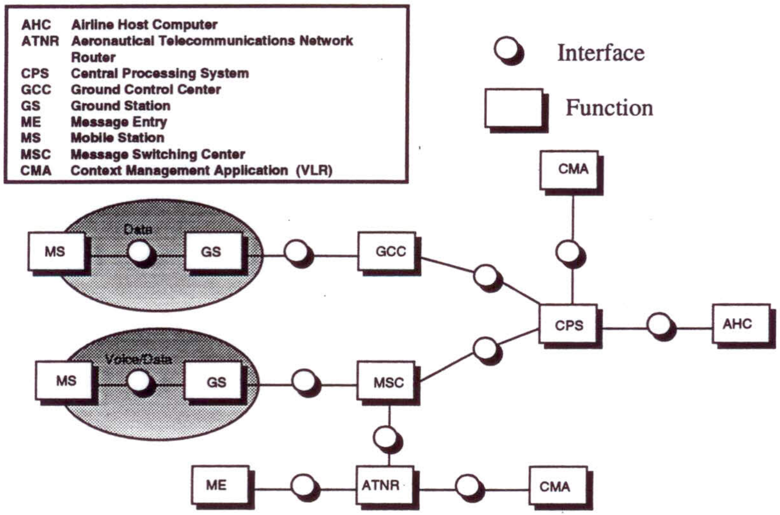


Figure 2.1-2 Network Context Diagram: Civil/Aviation

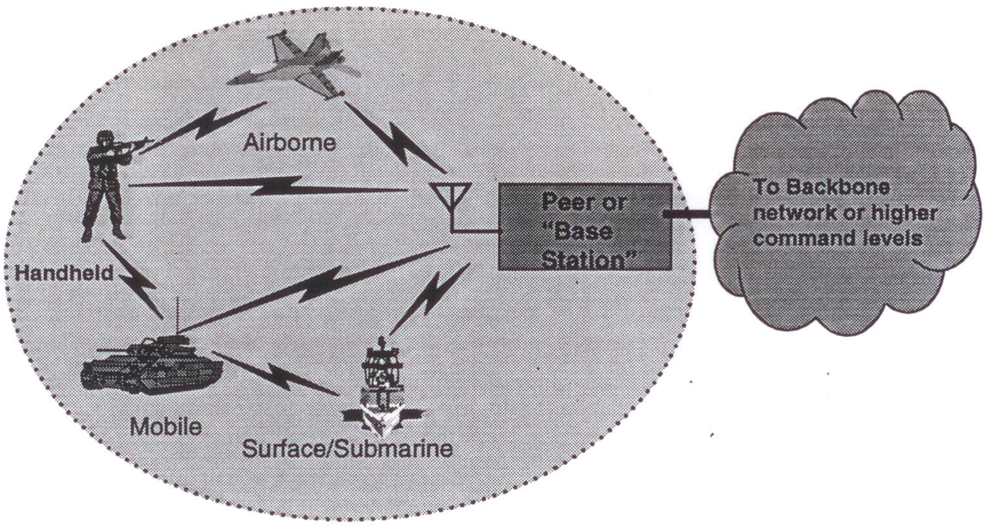


Figure 2.1-3 Network Context Diagram: Defense Applications

2.2 Services and Parameters

This section provides an overview of the wireless services, supporting standards, critical defining parameters, and required protocols that the MMITS standards recommendations development activities will use as a requirements base.

The goal of this section is to provide the data needed to identify wireless services and standards recommendations according to anticipated capabilities of various classes of software radio platforms.

The Terms and Definition Table defines the different categories and types of applications. These include terms to be defined within a framework where these guidelines may serve both a current vision of MMITS as a software radio, as well as for future developments. Targeted future possibilities include devices and systems which are functionally defined through the digital signal processing and software that these devices feature within an architecture that allows for multiple standards and information transfer services. Near-term applications may include combinations of cellular, pagers, cordless telephones, and possibly GPS. The ability to also include a low earth orbiting satellite (LEO) and International Maritime Satellite (INMARSAT)-type satellite radio function, along with the cellular and other services, could also be envisioned. Further growth to include data networking, and the possibility of other services, open up more applications than can be currently categorized usefully. Thus, the categories of applications provide some flexibility and abstraction, so that further applications may be defined, while fitting within the same overall framework.

The terms "applications," "services," and "functions" are used here. Their relationship is best seen by reference to the terms definition table. In order of generality, "applications" is the most general, "services" refer to what technology provides and a user receives (e.g., cellular), and "standard" to the specific standards (as defined by standards organizations) provided (e.g., IS-95). Other definitions are included in the terms definition table.

Examples of actual applications recommendations are in a set of tables defined by the standards they fit in Section 2.2. Other items in the Terms and Definition Table (e.g., simultaneity) are of interest for MMITS applications. Although the MMITS Forum does not intend to recommend standards in these areas, the definitions serve as points of reference for future application descriptions in MMITS. Further, work in identifying MMITS applications will be carried out as part of the technical working groups.

The recommendations include applications and the functional parameters associated with those applications. In many cases parameters are included by reference to the standard (or other reference) they are associated with. The tables are organized around the major categories, and the markets. A set of tables, for each case, provides the parameters, applicable standards recommendations, and standards references.

2.2.1 Terms Definitions

Table 2.2.1-1 below defines the terms used. Recommendations are defined by class and type. Examples are shown only to clarify their use, and in no way imply that these are the only types to be defined, nor necessarily the most important ones. Recommendations are categorized as those pertaining to applications, interfaces, integration, and form factor. These represent only guidance to the Architecture Subcommittee for the standards recommendations setting process.

Table 2.2.1-1 Terms and Definitions

Category	Type of Recommendations	Definition of Term	Examples
Applications			
	Service	Information transfer capability provided	1. Cellular 2. Mobile Satellite Voice
	Standard	Specific type and protocol of air and user interface, defined by standards organizations	1. AMPS, 2. GSM, 3. GPS
	Standard Parameters	Technical parameters associated with specific standard	1. AMPS Channel Bandwidth: 30 kHz; 2. GSM Channel Bandwidth: 200 kHz
Application Features	Simultaneity	Simultaneous standards	1. GSM and GPS
	Reconfigurability	Method for changing standards	1. User Selectable, 2. Automatic for Best BER
	Environment	Specific environment factors such as RF or Mobility	1. User mobility up to 100 MPH 2. Fading in urban terrain
Interfaces			
	User Interface	Type of user interface	1. Portable voice handset
	Service Interface	Type of interface with service provider, often included by reference to standard air interface	1. RF interface into Base Station
	Applications Program Interfaces (API's)	API's Allowed or Disallowed; if blank, none are specifically Disallowed	1. Optional encryption and/or authentication API's
Integration			
	Interworking	Type and mode of interface to other open architecture systems	1. Seamless interface to PC for email messaging 2. Interoperability with existing systems
Form Factor			
	Size	length*width*height	
	Weight	weight	

Category	Type of Recommendations	Definition of Term	Examples
	Power	-total power consumption, -type of power supply, -length of time with power supply without recharge/service, -type of recharge/service	
Other			

2.2.2 Service Parameter Tables

The commercial, Civil Government, and defense spectrum allocations in the US are presented in Figure 2.2.2-1. An overview of multiband requirements is illustrated in the example of the U.S. spectrum allocations shown in the figure. Similar situations exist in other countries and regions. Figure 2.2.2-2 is an example of the Japanese spectrum allocation and Figure 2.2.2-3 is a European example.

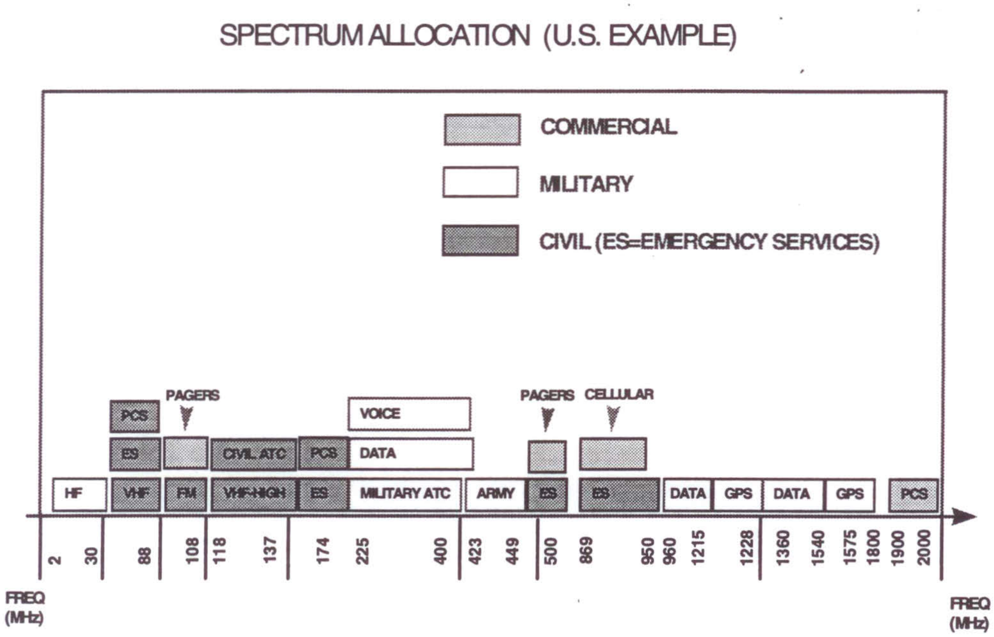


Figure 2.2.2-1 U.S. Spectrum Allocation

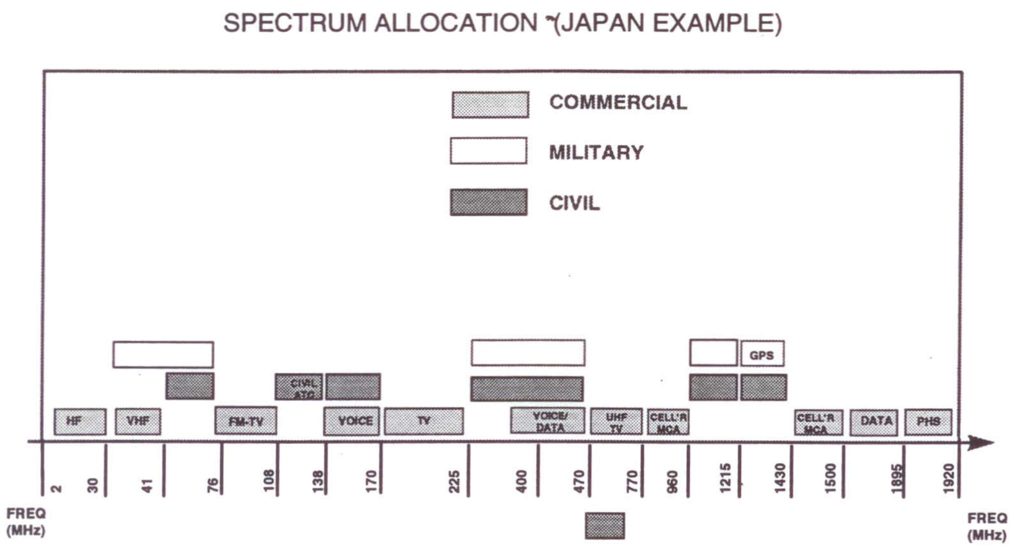


Figure 2.2.2-2 Japan Spectrum Allocation

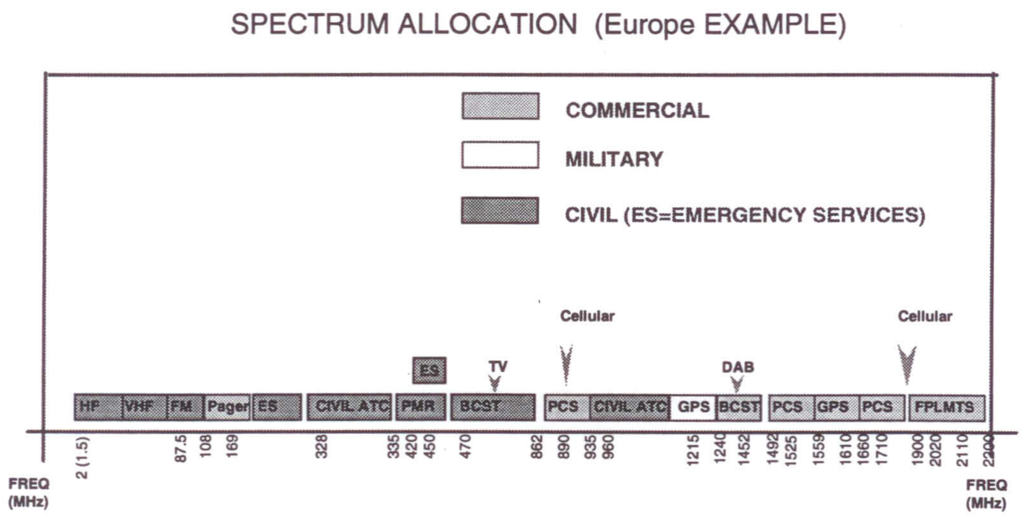


Figure 2.2.2-3 Sample European Spectrum Allocation

Examples of the Service/Standards and the critical parameters are defined in the following tables:

- Table 2.2.2-1, Representative Commercial Wireless Standards and Parameters
- Table 2.2.2-2, Representative Civil Wireless Standards and Parameters
- Table 2.2.2-3, Representative Military Wireless Standards and Parameters

Table 2.2.2-1 Representative Commercial Wireless Standards and Parameters

STANDARDS	Freq. (MHz)	Channel Bandwidth	Raw Data Rate	Modulation Format	Voice Coding	Multiple Access	Duplex	Tx Power
AMPS	TX 824 - 849 RX 869 - 894	60/30 kHz	Analog	FM	Analog	FDMA	FDD	Handset: 600 mw
IS-54/136	TX 824 - 849 RX 869 - 894	60/30 kHz	48.6 kbps	DQPSK	VSELP/8kbps ACELP/ 9.4kbps	TDMA	FDD	Handset: 600 mw
GSM	Tx 880 - 915 Rx 869 - 894	200 kHz	270.833 kbps	GMSK	RPE-LTP 13 kbps	TDMA	FDD	Handset: 2 W
IS-95	TX 824 - 849 RX 869 - 894	1.25 MHz	1.2288 Mcps/1.2-14.4 kbps	OQPSK	QCELP 13.2 kbps	CDMA	FDD	Handset: 200 mw
CT-2	864 - 868	100 kHz	32 kbps	GFSK	ADPCM 32 kbps	FDMA	TDD	
POCSAG	929 -932	25 kHz	2.4 kbps	FSK		TDMA	FDD	
Reflex (Narrowband PCS)	TX 901 - 902 Rx 929 - 932 Rx 940 - 941	Rx 25 / 50 kHz Tx 12.5 kHz	Rx 12 / 24 kbps Tx 9.6 kbps	4FSK		TDMA	FDD	
RAM	Tx 935 - 941 Tx 896 - 901	12.5 kHz	8 kbps	GMSK		FDM	FDD	3 W
ARDIS	Tx 851 - 866 Rx 806 -826	30 kHz	4.8 to 19.2 kbps	proprietary		FDM	FDD	
ISM Band (U.S.)	902 - 928 MHz 2.4 - 2.485 GHz 5.75-5.85 GHz	wide variety No Standard	WLAN, WPBX cordless phone DS-1 links	FCC Part 15 Spread Spectrum DS & FH		Typically FDMA	Typically FDD	1 W (USA)
DECT	1880-1900	1.726 MHz	1.152 Mbps	GFSK	ADPCM 32 kbps	TDMA	TDD	250 mW
DCS 1800	Tx 1805 - 1880 Rx 1710 - 1785	200 kHz	270.833 kbps	GMSK	RPÈ-LTP 13 kbps	TDMA	FDD	1W
PCS 1900	1800 - 1950	200 kHz	270.832 kbps	GMSK	CELP 13 kbps	TDMA	FDD	Handset: 600 mw
IS-136+	1800 - 1950	6030 kHz	48.6 kbps	DQPSK	ACELP 7.4 kbps	TDMA	FDD	Handset: 600 mw
IS-95+	1800 - 1950	1.25 MHz	1.2288 Mbps	OQPSK		CDMA	FDD	Handset: 200 mw
IS-661 Omnipoint	1800 - 1950	2.5 MHz				FDMA/TDMA/ CDMA	TDD	Handset: 600 mW
PACS	1930-1990 1850-1910	300 kHz	64 kbps	$\pi/4$ OQPSK	ADPCM 32 kbps	TDMA	FDD	

STANDARDS	Freq. (MHz)	Channel Bandwidth	Raw Data Rate	Modulation Format	Voice Coding	Multiple Access	Duplex	Tx Power
PDC	Tx 925-956, 1477-1501 Rx 810-818, 870-883, 1429-1453	50/25 kHz	42 kbps	π/4 OQPSK	PSI-CELP 3.45 kbps	TDMA	FDD	Handset: 600 mW
PHS	1895-1918	300 kHz	384 kbps	π/4 OQPSK	ADPCM 32 kbps	TDMA	TDD	Handset: 10 mW (Avg.) 80 mW (Burst)
IRIDIUM (mobile user segment)	1616 - 1626.5	3,840 channels total (48 cells per satellite, 80 channels per cell on average)	50 Kbps burst to provide voice at 4.8 Kbps and data at 2.4 Kbps	QPSK		FDMA/ TDMA	FD	

Table 2.2.2-2, Representative Civil Wireless Standards and Parameters

Standards	Freq. (MHz)	Channel Spacing	Raw Data Rate	Modulation Format	Multiple Access	Duplex	Tx Power
VHF Digital Link	117.975-137	25 kHz	37.5 kHz	D8PSK	TDMA	HD	
VHFAir/Ground	117.975 - 137.	8.33 kHz/25 kHz	Analog	AM-DSB	FDM	HD	
VHF Air/Ground	108.0 - 117.975	25 kHz	Analog	AM-DSB	FDM	Simplex	
Maritime VHF	156-165(US) 174(EU)	5 kHz	Analog	FM +/-5kHz	FDM	HD	
APCO-25	FCC Part 90	12.5/6.25 kHz	9.6 kbps	APSK/C4FM	FDM	FD	

Table 2.2.2-3, Representative Military Wireless Standards and Parameters

STANDARDS	Freq. (MHz)	Channel Spacing	Raw Data Rate	Modulation Format	Multiple Access	Duplex	Tx Power
UHF Voice/Data 188-243	225-400	25 kHz	16 kbps	AM/FM	FDM	HD	
SATURN	225-400	25 kHz	16 kbps	CPFSK	FDM	HD	
Have Quick	225 - 400	25 kHz	16 kbps	AM-DSB/ASK	FDM	HD	
SINCGARS	30 - 88	25 kHz	16 kbps	CPFSK	FDM	HD/FD	
Satcom/DAMA	225 - 400	25 kHz	19.2 kbps burst	various	TDMA - DAMA	HD/FD	
HF Analog 188-141A	1.5 - 30	3 kHz	Analog	SSB, ISB	FDM	HD	
HF Data Modems 188-110A	2 -30	3 kHz	9600 bps	Various	FDM	HD	
HF ALE 188-141A	2 -30	3kHz	75 bps	FSK	FDM	HD	
EPLRS	423 - 449	3 MHz	56kbps	MSK/CPSK	TDMA	HD	
JTIDS	960-1215	3 MHz	384 kbps	MSK/CCSK	TDMA	HD	
VRC-99	1350 - 1850	5 MHz	10 Mbps	QPSK	TDMA/FDM	HD	
NTDR	225 - 450	2.4 MHz	500kbps	QBL-MSK/ CQPSK	CSMA/CA/ FDM	HD	
DWTS	L - Band		2 Mbps Max		FDM/ Trunking	FD	

2.2.3 Requirements

2.2.3.1 Handheld Requirements

Handheld system solutions are driven by a set of requirements which differentiate them from mobile and fixed systems. The most notable are power, cost, volume and weight. Handheld solutions have to be in a form factor that is convenient for a person to hold and carry and to have the longest possible battery life. They are typically battery powered using transmit power ranging from 1 mW to 3 W (limited by health concerns). Typical commercial cellular and PCS single mode single band handsets today deliver in the range of from 9 to 150 hours of standby time. A recent solicitation from the US military for special unit operations sought 48 hours of "use" on a single battery charge. Another factor related to power management and form factor is heat dissipation. There is no space for cooling devices such as fans and not enough battery power available to afford solutions that generate large amounts of heat. Another aspect of handheld systems is the focus on cost. Since the number of units fielded is relatively large in proportion to other network components, the focus on cost minimization is significant. This handheld architecture is based on these requirements.

2.2.3.2 Mobile System Applications and Requirements

The following sections outline a series of operational requirements and applications for mobile units. These mobile units are applied in the military, Civil Government, and private land mobile environments.

Applications

Five mobile information transfer system models will be considered:

- Military land vehicle,
- Aeronautical,
- Naval shipboard,
- Manpack, and
- Automotive information transfer systems.

Common characteristics

The following common features are often included for mobile information transfer systems deployed in the five application environments:

- Operation in a frequency range of nominally 2MHz (1.5 MHz for some European military service) to 2GHz
- Exciter power of 2 watts, into a power amplifier.
- Multi-channel operation
- Consideration of co-site performance
- Bridging capability within the system

- A user interface to control each channel
- Functionally controlled by software so that the waveform executed by each channel is determined by the software loaded.

MILITARY LAND VEHICLES

Environment

Implementation of the digital battlespace requires communication between force elements on the move and in fixed positions. Military land vehicles include tanks and other vehicles participating in the battle and supporting it. These vehicles need to participate in nets that provide command, control, situational awareness, sensor data, and processed intelligence to all levels of command. Manpack systems used by individual warfighters although participants in the same nets, are treated in a separate model due to their differing form factor characteristics.

Description of the System

The mobile information transfer system will be installed in a vehicle, and will receive power from the vehicle electrical system or from an auxiliary power system. Antennas will be located either on the vehicle or a short distance from it.

For operation in a tank, the user interface of the information transfer system will connect into the vehicle intercommunication system, and will normally be controlled by the tank commander. It will receive situational data from tanks in the same unit and from central resources for display. It will transmit sensor data, including GPS position data and vehicle operational data to higher level units. It will transmit commander's orders to subordinates as either voice or display data in real time to support unit maneuvers.

Installed in a High Mobility Multi-purpose Wheeled Vehicle (HMMWV), the information transfer system will typically support a tactical operations center or other field headquarters. While on the move personnel can communicate on voice and data channels. At the site, connection will be made to the headquarters local area network, making radio channels available to the commander and personnel manning the center. In order to provide dispersion the unit will operate at a distance of 25 to 100 meters from the central facility.

Operation of the System

The mobile radio in a land vehicle operates in wide variety ways, each of which includes the following characteristics:

- The system operates with a variety legacy waveforms that may include the following as examples:
  - Global Positioning System (GPS)
  - Joint Tactical Information Distribution System (JTIDS)

- Enhanced Position Location Reporting System (EPLRS)
- Packet Radio (VRC-99)
- Single-Channel Ground and Airborne Radio System (SINCGARS/SIP)
- High Frequency (HF)
- UHF Air-ground voice radio (Have Quick Saturn)
- Trunked radio 10 Mbps
- Near Term Digital Radio (NTDR)
- Cellular, PCS

- Typically the interface to the user is modular and includes provisions for internetworking functions like the following:
  - FDDI
  - Ethernet 100 Mbps
  - TCP/IP
  - RS232
  - RS422

- The radio incorporates appropriate INFOSEC and Transient Electromagnetic Pulse Standard (TEMPEST) controls

- Front panel fill and over the air rekeying integrate with the INFOSEC system

- Participation in and adaptive hand-off between operational clusters

Support for division level networks of up to 5000 nodes

Functions of the Information transfer system

The information transfer system will be the backbone of digital battlespace operations wherever land lines are not available. Functionality will vary from replicating the capability of a simple radio for voice contact to acting as a small digital switch.

With its multi-mode capability, the information transfer system will act as a repeater so that an individual equipped with a legacy radio such as SINCGARS can talk directly with support aircraft using UHF Have Quick through a information transfer system.

Implications of mobility on the information transfer system

Mobility implies the following:

- An ability to move rapidly from one operating location to another while maintaining the full capability to communicate
- Operate without dependence on a power line
- Mitigate co-site self jamming
- Modular extension and replacement
- A form factor smaller and lighter than the equipment replaced

Important Parameters

Key operational parameters are:

- Frequency
- Modulation type
- Timing
- Orderwire
- Power level
- Keys and hopsets

AERONAUTICAL

Environment

As part of the communications, navigation, and IFF (Communication, Navigation and Identification - CNI) system of both military and commercial aircraft, a number of different equipments have been traditionally installed in each tail number. When an aircraft is designated for a specific mission or to fly a route in a specific portion of the world, there is a planning element to ensure that it can communicate with other stations as necessary. With a programmable information transfer system, any aircraft equipped with suitable antennas and external RF equipment could be reprogrammed to interoperate with designated waveforms and protocols.

Description of the System

Installation of the information transfer system technology into an aircraft is largely a matter of form factor. If implemented on suitable circuit cards, the system resources can be directly installed in the necessary ATR of SEM-E package for the aircraft type. The internetworking function will necessarily need to match with the aircraft CNI system.

Operation of the System

The information transfer system will operate in a manner similar to other radio equipment installed on the aircraft. The operators panel will appear as an additional display in the cockpit display, and presets will appear on the channelized control display.

Functions of the Information transfer system

The information display system permits the aircraft crew to communicate on any channel for which appropriate software has been loaded into the system archive. Over the air software upload is also possible. Then the crew can talk with ground stations, other aircraft, and satellites. Aircraft sensor data can be downloaded, and graphic data uploaded to the aircraft.

Implications of mobility on the information transfer system

Use in an aircraft involves conformance with the designed form factor, and the replacement must weigh less than previously installed equipment. Power is derived from the aircraft power bus.

Important Parameters

Key operational parameters include:

- Frequency
- Modulation type
- Timing
- Power level
- Keys and hopsets

NAVAL SHIPBOARD

Environment

The area of shipboard communications includes all information transfer between naval vessels and an external entity. This includes ship-to-ship communications, ship-to-shore communications, ship-to-aircraft communications, and ship-to-satellite communications. Both commercial shipping and defense naval communications are included.

Description of System

The information transfer system installation is in racks in interior compartments of a ship where it becomes a part of the shipboard communications facilities. The user interface will be used primarily by radiomen to establish presets available from other stations around the ship. Power is from the ship's generators.

The nature of shipborne communications requirements places particular strains of the modularity aspects of a MMITS radio. Some interesting considerations include:

- Extensibility from as few as five channels per platform on a small ship to over 100 channels per platform on a larger ship.
- Adaptive bandwidth variability from 3 kHz to 3 GHz.
- Multi-media communications for voice, data, video, facsimile, and message signals.
- Security including red and black throughput, a range of crypotographic functions and standards, and external cryptographic devices.
- Demand-assigned or dedicated communications channels accessible by a single user or user group.
- Guaranteed quality of service describing priority, bandwidth, and reliability.
- Variable ranges from line-of-sight communications to 11,000 km.

- Co-site interference control mechanisms to manage interference between collocated receiver and transmitters.
- Remotely configurable through a standard network management protocol such as SNMP.
- Adjacent channel interference control.

Operation of System

The system will provide communications channels to support diverse services. Examples of current services are listed here, primarily emphasizing US Navy communications services.

- Tactical Group Communications circuits for battle group maneuvering, urgent tactical communications, intelligence information, operations and administrative communications, and communications with units deployed to join the battle group.
- Anti-Submarine Warfare (ASW) Communications circuits for ship-to-ship and ship-to-air monitoring of submarine activities.
- Anti-Surface Warfare (ASuW) Communications circuits exchange tactical and air, surface and sonar information between ships.
- Anti-Air Warfare (AAW) Communications circuits for the dissemination of information for aircraft control and air raid reporting between ships.
- Electronic Warfare (EW) Communications circuits to control jamming, search and direction finding and to exchange information.
- Air Operations Communications circuits for aircraft and helicopter control.
- Tactical Air Communications circuits for control of aircraft engaged in operations.
- Amphibious Communications circuits to communicate between offshore platforms, landing force elements and beach headquarters.
- Naval Gunfire Communications circuits to conduct, coordinate and control naval fire activities.
- Submarine Communications circuits to communicate between submarines, submarines and ships, and submarines and submarine operating authorities.
- Data links to transfer digital signals between ships, ships and aircraft and ships and shore stations.
- Distress Communications circuits for civilian and military search and rescue operations.
- Mine Countermeasure (MCM) Communications circuits to exchange mine countermeasure maneuvering and tactical information.
- Harbor Communications circuits are used for civilian and military navigation.
- UHF Fleet Satellite circuits for long-haul communications between ships and shore facilities.
- Long-Haul HF Communications circuits used on many platforms as the primary ship-to-shore communications medium. Allied forces (NATO) use HF and UHF circuits.
- Strategic Submarine Warfare Communications circuits to meet the special communications needs of ballistic missile submarines and attack submarines.
- Navigation circuits to give position, velocity and time information to vessels at sea.
- Telephone circuits from ships at sea to shore via (commercial) satellite communications.

In the case of the US Navy, the system will interface with network management systems such as Automated Digital Network System (ADNS) to provide automated management of communications resources and automated dissemination and support of fleet communications planning.

Functions of Information transfer system

Functional units of the information transfer system must be consistent with the modular concepts developed in the MMITS architecture. RF capabilities range from VLF (3 kHz - 30 kHz) to UHF (300 MHz - 3 GHz). RF also will provide adaptive functionality, including Link Quality Analysis and Automatic Link Establishment and TRANSEC techniques to prevent signal detection and jamming. The modem converts analog and digital radio traffic into a standard waveform. This includes modulation, interleaving, forward error correction (FEC) and multiplexing with various access techniques including frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA). INFOSEC uses various cryptographic techniques and/or interface with external cryptographic equipment to insure secure voice and data communications. INFOSEC also supports special cryptographic encoding of DAMA orderwire and other channel control messages to secure the identity of the channel controller. Message Processing includes functions for LAN communications, data compression, and vocoder functions.

Implications of mobility on the information transfer system

As with other forms of wireless mobile communications, loss of signal is a problem. Most ships move relatively slowly. Once communications are established, loss of signal tends to be related more to atmospheric conditions and time of day than to range of motion. Sea state is an important environmental factor. Careful placement of antennas is required to insure a continuous signal despite severe pitch and roll. In addition, external radio modules must be able to withstand harsh environmental conditions and internal information transfer system modules must be ruggedized and securely mounted.

Important Parameters/Range

The operational parameters include operating frequency, operating time period, data type, security label, quality of information transfer, and participants. Where possible, these parameters will be negotiated between systems and will be transparent to the end users.

MANPACK

Environment

The current trend in battlespace doctrine calls for electronic connection to each warfighter. Sensor data including video and laser ranging information is fed back to intelligence centers where the situation analysis is kept current. Then the location of friendly and enemy elements can be fed back to individuals and elements for their tactical use. Command and control information also is fed forward.

DARPA, the US ARMY, and the US Marine Corps are conducting experiments such as Small Unit Operations, Sea Dragon, and Extended Littoral Battlespace. These experiments will form the basis for the future doctrine of land forces in the information age.

Description of the System

The manpack communications system will have to be lightweight; have low power consumption; have a simple, user friendly human interface; possess low probability of intercept and low probability of detection in order to enhance operator survivability, and be rugged enough to withstand the environmental rigors of a combat situation.

Operation of the System

The communication system will be multifunctional (voice, data, imagery, and video), multimode (legacy and new waveforms), provide high resolution location of the operator; and be capable of secure operation.

Functions of the Information transfer system

In order to communicate with current combat net radios, the system would have a VHF mode and with current Air Force equipment, would have to have a UHF mode. A cellular capability is envisioned and could operate with a mobile base station from an airborne platform like a unmanned aerial vehicle (UAV). Location could be provided by the Global Positioning System or in the case of dense foliage or inside buildings, could have a Loran or TDOA type capability. The capability to broadcast VHF (ground) and UHF (air) simultaneously to call for timely artillery, mortar, and rocket fire support and call for air support would be required for small units to fight and survive. A capability to receive imagery and video from the global broadcast system is envisioned for map updates, enemy positions, non-combatants locations, etc. Over-the-air keying of crypto would also be required. A paging capability is envisioned to alert individuals scattered over a large area of events such as impending nuclear, biological, or chemical attacks.

Implications of mobility on the information transfer system

The most obvious implications are varying propagation effects and non-disruptive handoff as the unit moves. Waveform and protocol optimization also become issues.

Important Parameters

The frequencies of operation are important and should cover at least 30 MHz to 2 GHz. Receive frequencies of wideband information could be much higher but schemes such as receiving the GBS broadcast on a UAV and retransmit a portion of the broadcast in L-Band have been investigated. Bandwidth estimated are 10 MHz per channel. Data rate estimates are 1.5 Mbps for receiving wideband but much lower transmit estimates due to power limitations. Range estimates are 10-15 KM ground-to-ground and many miles ground-to-air.

AUTOMOTIVE INFORMATION TRANSFER SYSTEMS

Environment

The time period from 1980 to 1995 has seen introduction of a large number of microprocessors and controllers dedicated to such functions as engine control, automatic braking systems, transmission control, sound system, GPS, cellular, and route display. With the introduction of the Intelligent Transport System, a number of these functions can be combined with wireless communications. As they are brought together, the flexibility of an information transfer system offers the opportunity of upgrading system functionality by adding software to the existing hardware.

Description of the System

A single unit in the vehicle, using the information transfer system architecture, provides RF receive and transmit channels, audio sound, information display, voice synthesis, and processing. Power is received from the automobile electrical system.

Operation of the System

An increasing number of services are available to motorists on highways using RF links. The Intelligent Transfer System provides a capability utilize these services. It also permits the user to adapt easily to new services as they become available by loading new communications configurations into the system.

Entertainment is provided by the system through audio amplifiers and loudspeakers. Access to a number of voice communications facilities is provided through a single handset. By receiving the GPS waveform, vehicle location, direction, speed, and the time are available. That information can be used in conjunction with stored map and route information to provide guidance to the desired location. As intelligent highway services are offered, they can be monitored by this system.

Functions of the Information transfer system

- AM radio
- FM radio
- CD player
- Stereo amplifier
- GPS position location
- Cellular phone
- PCS services
- Paging
- Amateur radio
- Citizen's band
- Talk between cars

- Traffic information
- Route display
- Voice announcement
- Vehicle Coordination:
    - Congestion rerouting
    - Platooning
    - etc.

Implications of mobility on the information transfer system

As with any cellular or PCS service, the motion of the car introduces problems with Rayleigh and Ricean fading that will have to be overcome to provide continuity of service. Extreme temperature excursions must be accommodated.

Important Parameters

The system must accommodate the operational parameters of the services to be provided.

3.0 Architecture

This section focuses upon the Modular, Multifunction Information Transfer System (MMITS) architecture. The architecture is a representation of a MMITS system that rationalizes, arranges, and connects components to produce the desired functionality. This architecture is intended to form the basis for specific implementations of a system that meets functional MMITS requirements and also provides upgrade paths for handling enhanced, evolving and new requirements. This feature of "future proof" architectures is a fundamental goal and challenge for the MMITS Forum.

Figure 3.0-1 illustrates the scope of MMITS architectural discussions covered within this report. Section 3.1 discusses the MMITS architecture framework. It includes high-level models, functional interface diagrams, and interface interaction diagrams/tables. Section 3.2 presents specific examples of MMITS architectural models. Included in this report are models and discussions for handheld, mobile applications, and cross standards extensions representing the first three specific architectural work items undertaken by the Forum.

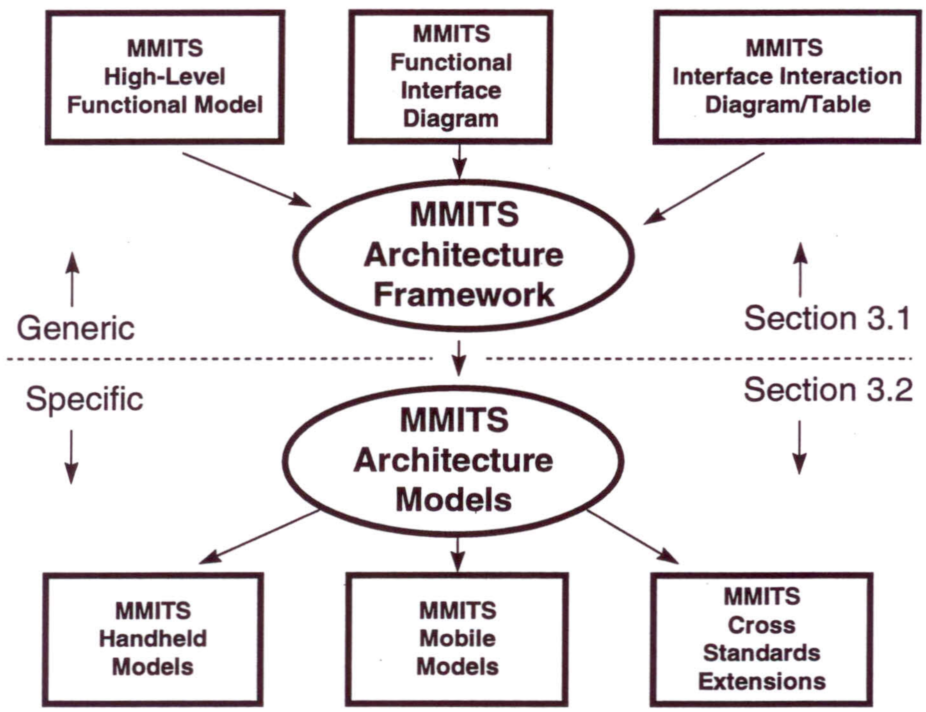


Figure 3.0-1 Scope of MMITS Forum Architecture Work

3.1 Framework

The strategy for meeting the "future proof" goal for a MMITS architecture is to provide high-level functional models that are capable of being mapped into specific software-defined information transfer devices such as handheld, mobile, and base station applications. Articulating the high-level architecture is key to establishing consistency among the specific architecture models to follow. The MMITS architecture framework addresses the higher level architectural aspects for software defined information transfer devices allowing latitude for a variety of specific implementations.

The MMITS open architecture is based upon a high-level generic functional model with functional blocks connected via open interface standards recommendations. The goal of the MMITS functional partitioning is to define an architectural framework that can be applied to specific implementation domains. Examples of these implementation domains are handheld, mobile, and fixed site or base station. The MMITS approach to standards recommendations is outlined in Table 3.1.1-1.

Table 3.1.1-1 Scope of the MMITS Approach to Open System Standards Recommendations

Standard Type	**MMITS Role**	**MMITS Approach**
Air Interface	Support identified standards through common architectural partitioning, Identify extensions to accommodate new MMITS capabilities	MMITS will identify and recommend extensions to the appropriate standards body
Internetworking	Support identified standards through common architectural partitioning, Identify extensions to accommodate new MMITS capabilities	MMITS will identify and recommend extensions to the appropriate standards body
API	Define	Definition based on MMITS functional model partitioning
Physical Interfaces	Select from existing open standards	Selections based on MMITS functional model partitioning and existing interconnect, backplane, and form factor standards
Analog/RF Interconnects	Identify applicable standards and approaches	MMITS will recommend where standards are lacking
User interface	None	Product dependent

Realization of a MMITS architecture has several characteristics:

Flexible - the ability, through band and mode selection, to access a desired part of the electromagnetic spectrum and to construct and decode desired waveforms or protocols through readily achievable reconfiguration.

Upgradeable - the ability to get more or better performance from the MMITS device through the insertion of improved hardware and software technologies. The architecture should provide for this in such a way as to localize the impact to the affected modules or components.

Scaleable - the ability to extend the functionality and capacity of the MMITS device to include multiple channels and networking, additional local connectivity and processing, or new evolving wireless services. Scaleability relates to the ability to support the addition of existing functions – quantitative growth.

Extensible - the ability to readily permit an addition of a new element, function, control, or capability within the existing framework. Extensibility pertains to the ability to support new functions – qualitative growth.

Development of a system architecture requires the establishment of three viewpoints of a system; the user/owner, the designer, and the developer. The user/owner is concerned with the operational and business attributes of the system, the system architecture designer concentrates upon identification of interconnection and communication of specific building blocks or functional modules, and the developer focuses upon specific implementation of the chosen functional modules, the technical architecture.

Standards recommendations arise from two sources. De facto standards are the result of wide acceptance and use in the marketplace. These standards recommendations typically emerge from proprietary work and are the intellectual property of the developer. If they are made available to third parties for development then they can be considered "open." These standards recommendations frequently evolve rapidly as the developer makes enhancements and adapts to emerging technological developments.

De jure standards are those established by a central body, and are issued in accordance with the guidelines established by that body for standardization. Although this process is inherently slower than de facto standardization, it has the advantage that original acceptance and subsequent changes take place through an established process. They are slower to become accepted, changes are well publicized in advance, and implement negotiated specifications. Implementers can develop products or systems to the specification with assurance that it will be stable.

MMITS will use both of these types of standards. De facto standards, such as bus architectures, permit access to a wide range of commercially available hardware and software items that can lead to convenient interaction and economies of scale. But the purpose of the MMITS Forum is to establish standards recommendations for key elements of target systems as a basis for standardization where open COTS resources are not available.

The MMITS Forum provides a mechanism whereby issues specific to software programmable radios can be resolved with an expedited standardization process. This approach permits systems using advanced technology to be fielded expeditiously with competition based on value added for customers and users rather than unproductive battles between essentially equivalent but different implementations.

Modularity is the key to successful implementation of open systems. Between modules are defined interfaces that are subject to standardization. Within a module the developer is free to implement functionality in the most effective way.

3.1.1 Functional Model

Open systems are those that contain open and standard internal interfaces between modules and open and standard external interfaces with other information systems. Open systems are defined by employing commercially successful non-proprietary interfaces, communications protocols and application program interfaces.

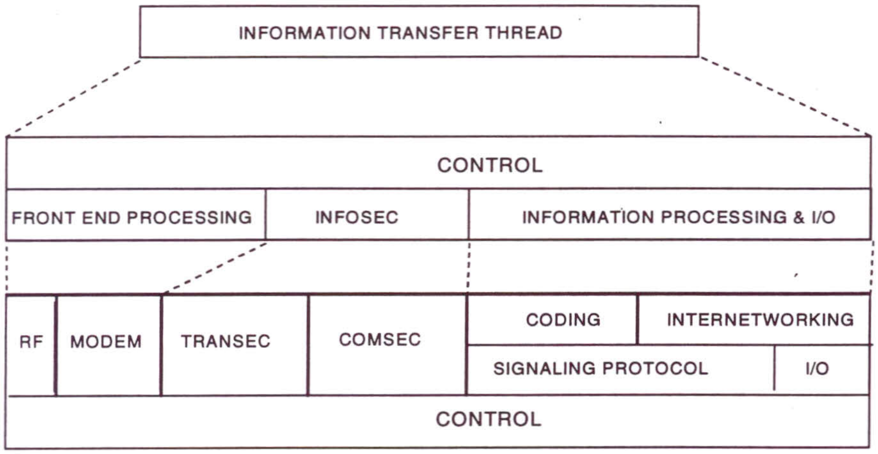


Figure 3.1.1-1 MMITS High-Level Function Model

Figure 3.1.1-1 is a high level hierarchical functional model for a modular, multifunction, information transfer system (MMITS). Three views of increasing complexity are presented. The top level view is a simple representation of an entire information transfer thread. The left side interface is the air interface. The right side interface is the wire side and user interface. The next level view identifies a fundamental ordered functional flow of four significant and necessary functional areas; (1) front end processing, (2) information security, (3) information processing, and (4) control. It is noted that diagrams and processes discussed within this document, unless otherwise specified, are two-way devices (send and receive). Note that the functional model as shown in this figure is not intended to show data or signal flow.

Front end processing is that functional area of the end user device that consists generically of the physical air (or propagation medium) interface, the front-end radio frequency processing, and any frequency up and down conversion that is necessary. Also, modulation/demodulation processing is contained in this functional block area.

Information security (INFOSEC) is employed for the purpose of providing user privacy, authentication and information protection. INFOSEC within the MMITS model, consists of two fundamental processes; transmission security (TRANSEC) including those processes such as frequency hopping or direct spread spectrum or other signal variation coding, and communications security (COMSEC) which is the algorithmic encryption and decryption of the digital or digitized analog information. Another primary function is the management of INFOSEC, key management. In the commercial environment, this protection is specified by the underlying service standard while in the defense environment, this protection is of a nature that must be consistent with the various Governmental doctrines and policies in effect.

Content or information processing is for the purpose of decomposing or recovering the imbedded information containing data, control, and timing. Content processing and I/O functions map into path selection (including bridging, routing, and gateway), multiplexing, source coding (including vocoding, and video compression/expansion), signaling protocol, and I/O functions.

Figure 3.1.1-2 demonstrates that the MMITS Architecture features two important attributes, scaleability and extensibility. The advantage of this architectural approach is that development can proceed asynchronously in different parts of the system. In other words it supports an evolving design process. The high level architecture presented in Figure 3.1.1-1 is scaled in one part of the figure to show a "better modem" and "better TRANSEC." These improved features could mean increased processing capability, lower power operation, smaller size, etc. The importance of the scaleability attribute is that the MMITS architecture accepts modular improvements in a seamless and transparent fashion. The figure also demonstrates how the architecture may be extended to show a multiple channel configuration.

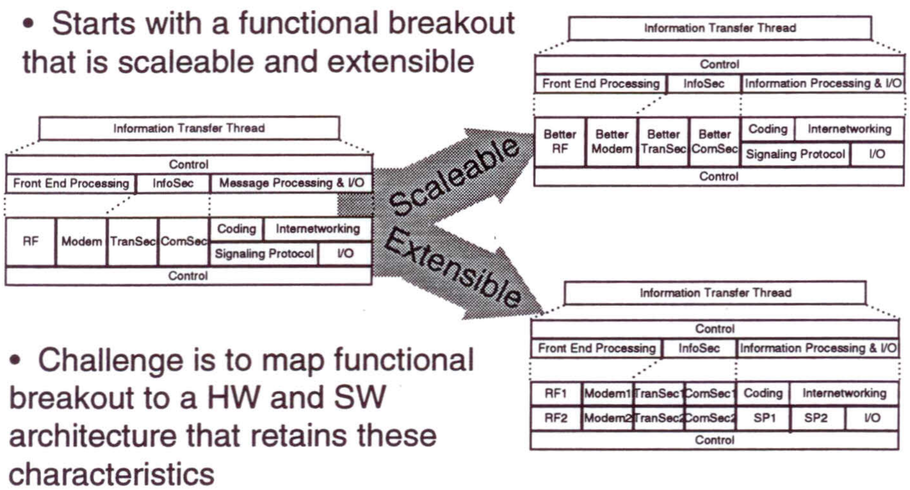


Figure 3.1.1-2 MMITS Architecture Evolution Process

Figure 3.1.1-3 illustrates that the MMITS functional model maps to three specific applications: a handheld unit, a mobile system, and a basestation. The MMITS functional model is common to each of the implementations with more detailed descriptions provided in section 3.2.1 for the handheld model and section 3.2.2 for the mobile model. The basestation model is similar to the mobile model.

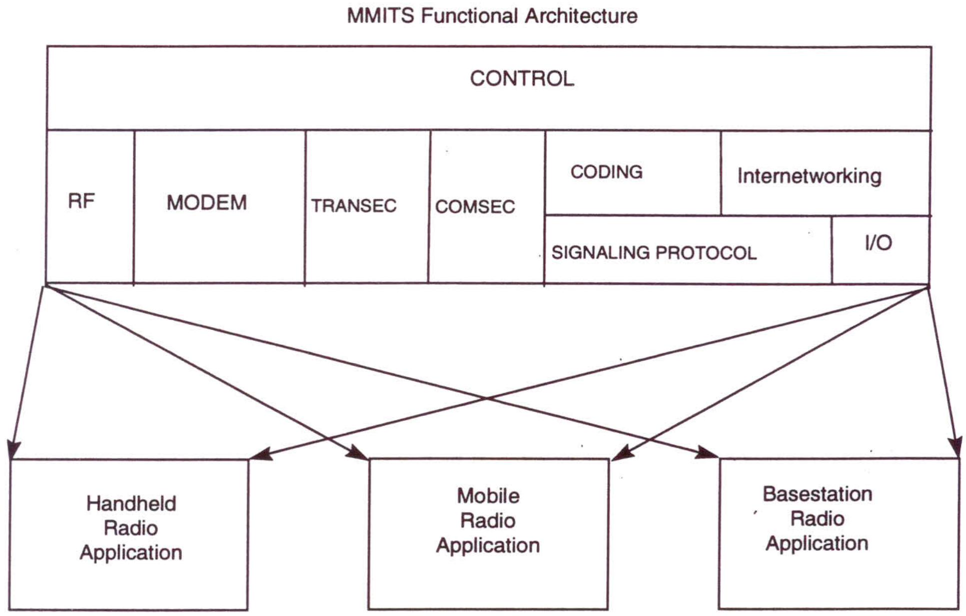


Figure 3.1.1-3 One Common MMITS Functional Architecture Maps to Handheld, Mobile and Basestation Radio Configurations

The MMITS architecture consists of functions connected through open interfaces, and procedures for adding software specific tasks to each of the functional areas. The software necessary to operate is referred to as a software application. Figure 3.1.1-4 is a diagram of the MMITS open architecture showing six independent subsystems interconnected by open interfaces. In this view the generalized MMITS functional architecture has been particularized by equating a subsystem definition to each functional area. In general this is not the case; subsystems will be determined by implementation considerations. Interfaces exist for linking software application specific modules into each subsystem. Each subsystem contains hardware, firmware, an operating system, and software modules that may be common to more than one application. The application layer is modular, flexible and software specific. The common software API layer, inferred in figure 3.1.1-4, is standardized with common functions having open and published interfaces. Peer-to-peer interfaces are neither required nor proscribed.

Figure 3.1.1.5 presents the MMITS functional interface diagram and demonstrates how the MMITS Architecture extends to the definition of functional interfaces. A representative information flow format is provided at the top of the diagram. Actual representations will be implementation dependent. Interfaces are identified for information and control. For example, information transfer is effected throughout the functional flow within the MMITS architecture

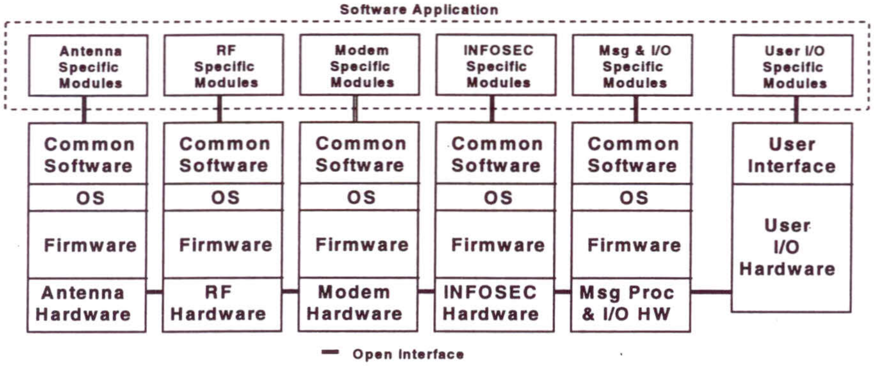


Figure 3.1.1-4 An Example Implementation of MMITS Software and Hardware Open Architecture

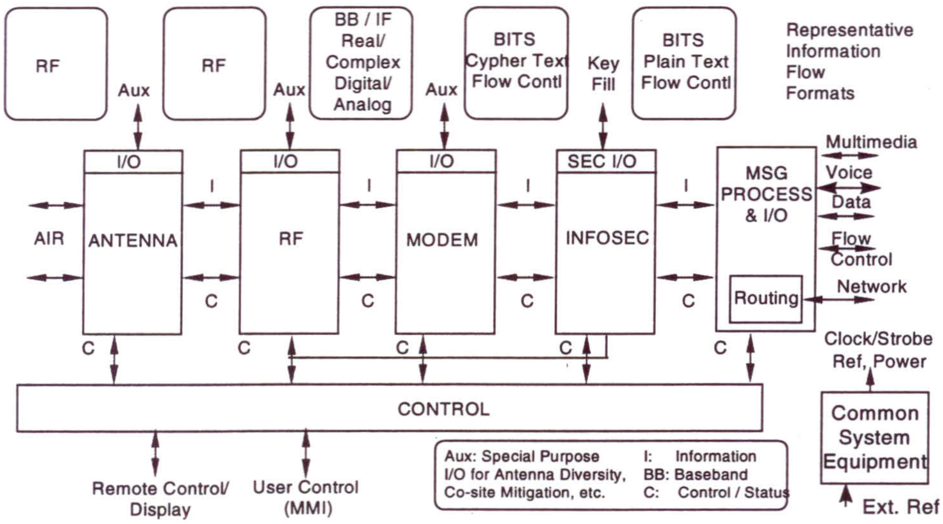


Figure 3.1.1-5 MMITS Functional Interface Diagram

to/from antenna-RF, RF-modem, modem-INFOSEC, and INFOSEC-Message Processing interfaces. Control and status is effected between the same interfaces as information and in addition control is effected between each functional module and one or more control points and interfaces. Auxiliary interfaces are also allowed, as shown on the diagram.

3.1.2 Interaction Diagram

Table 3.1.2-1 supports the functional interface diagrams by employing a matrix which plots information; [I] and control/status; [C] as a function of the appropriate MMITS interface. For example, the RF-Antenna interface contains information as well as control/status whereas the Air-Antenna interface contains information only. The matrix also identifies specific auxiliary interfaces for the purpose of transferring information among multichannels of a particular system or between systems in support of multichannel processing algorithms. Typical external interfaces are also identified within the matrix. The keys for the interaction diagram are:

- I: Information Flow Interface, i.e. information to be transferred over the communication link and information embedded in the signal-in-space waveform (e.g. training symbols, spread spectrum symbols).
- C: Control/Status Interface, i.e information transferred for the purpose of controlling other functional blocks or for generic radio control functions.
- Aux: External interface to a similar block (e.g. antenna to antenna interface for co-site mitigation) on the same or other radio channel.

Table 3.1.2-1 Interface Matrix

N^2 INTERFACE	AIR	ANT	RF	MODEM	INFOSEC	I/O	SEC. I/O	CONTROL	USER (MMI)
AIR		I							
ANT	I		I C	C				C	
RF		I C		I C	I C			C	
MODEM		C	I C		I C	I C		I C	
INFOSEC			I C	I C		I C	I C	I C	
SEC. I/O					I C				I C
I/O				I C	I C		I C	I C	I C
CONTROL		C	C	I C	I C	I C			I C
USER (MMI)						I C	I C	I C	
AUX		YES	YES	YES				YES	YES
WIRE SIDE I/O						YES			
FILL DEVICE							YES		
REMOTE CONTROL								YES	

This table gives the general view of the candidate interfaces under consideration for MMITS standards recommendations. Note that each module in the first column will require a detailed functional description to classify the functions that must be accomplished within that module but without specifying how those functions will be implemented. The internal requirements of the modules are only limited by the compliance with the input and output standardized characteristics as prescribed by MMITS.

Figure 3.1.2-1 is a graphical depiction of the interface matrix in the form of an NxN interface/interaction diagram. In Figure 3.1.2-1, each of the interfaces shown on each of the modules represent a potential for standards recommendations to establish an open architecture.

Table 3.1.2-2 describes the interface/interaction diagram interfaces with representative example information and/or control & status content. Table 3.1.2-2 offers a finer decomposition of those interfaces and examples of the content that are associated with each. The content of each information and control interface will necessarily need to be further developed, described, and bounded.

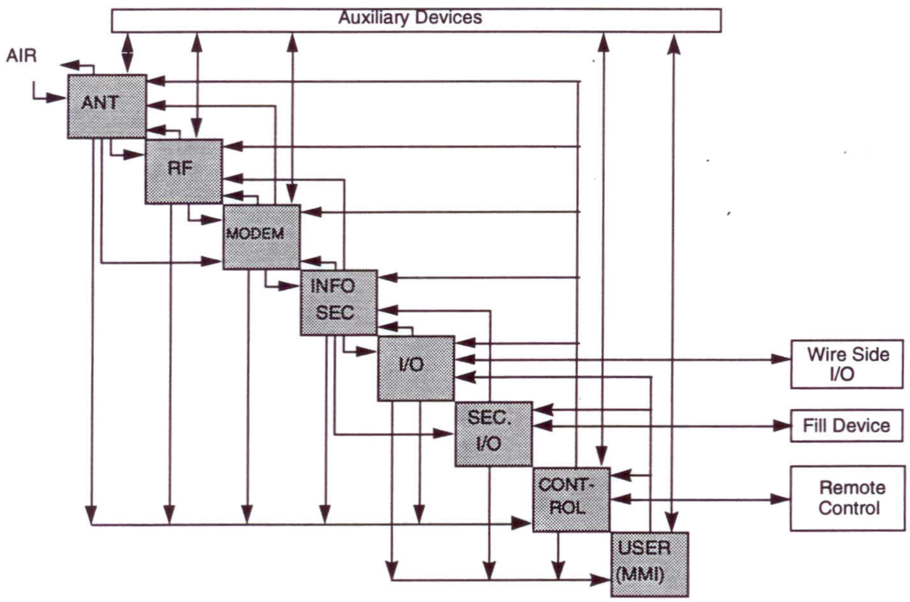


Figure 3.1.2-1 Interface/Interaction Diagram

Table 3.1.2-2 Interface Interaction Diagram Interfaces and Example Content

Interface	Transfer Type	Example Content
Air to Antenna	I	Information flow is defined by the air interface standard
Antenna to RF	I	Information flow in the RF signal
Antenna to RF	C	RF/Antenna status interfaces (beam steering, etc.)
Antenna to Modem	C	Status information interface for beam steering, etc.
Antenna to Control	C	Control status interface
Antenna to Environment Adaptation	C	Antenna status information for the purpose of adaptation algorithms
RF to Antenna	I	Information flow in the RF signal
RF to Antenna	C	RF/Antenna control interfaces (beam steering, etc.)
RF to Modem	I	Information flow in the RF/IF/Baseband signal
RF to Modem	C	Status interface for AGC, etc.
RF to Control	C	Control status interface
RF to Environment Adaptation	C	RF status information for the purpose of adaptation algorithms
Modem to Antenna	C	Modem control of antenna for beam steering, etc
Modem to RF	I	Information flow in the RF/IF/Baseband signal
Modem to RF	C	RF control such as frequency control and AGC
Modem to INFOSEC	I	Information (cipher text) flow within the received bits
Modem to INFOSEC	C	Modem status used by the INFOSEC function (transmit/receive, etc.)
Modem to Control	I	Information retrieved from the communication link data stream by the modem for control purposes.
Modem to Control	C	Modem status information
Modem to Environment Adaptation	C	Modem status information for the purpose of adaptation algorithms
INFOSEC to RF	I	TRANSEC information for waveform parameter variation
INFOSEC to RF	C	Mode control information such as disabling an RF function due to another mode being performed by another RF function such as an LPI channel.
INFOSEC to Modem	I	Information such as mode, preambles, key transfers
INFOSEC to Modem	C	TRANSEC information for waveform parameter variation, encrypted digital bits, flow control
INFOSEC to IO	I	Unencrypted bits
INFOSEC to IO	C	Mode switches, flow control
INFOSEC to Secure IO	I	Keys
INFOSEC to Secure IO	C	Key status, parity, alarms
INFOSEC to Control	I	Recovered information used in radio control algorithms
INFOSEC to Control	C	Status
INFOSEC to Environment Adaptation	C	COMSEC acquisition status
Secure IO to INFOSEC	I	Keys
Secure IO to INFOSEC	C	Control parameters
Secure IO to User	I	Front panel display, key status
Secure IO to User	C	Front panel keypad
IO to Modem	I	Bits when INFOSEC function not present
IO to Modem	C	IO derived modem control information, flow control
IO to INFOSEC	I	Bits
IO to INFOSEC	C	IO derived control information, flow control
IO to Control	I	Information parsed from the received bit stream

Interface	Transfer Type	Example Content
IO to Control	C	IO derived control information
IO to Environment Adaptation	C	Receive statistics
IO to User	I	Multimedia information
IO to User	C	flow control
Control to Antenna	C	Antenna control parameters
Control to RF	C	RF control parameters
Control to Modem	I	Control information for the Modem to insert into the information flow
Control to Modem	C	Modem control parameters
Control to INFOSEC	I	Information for the INFOSEC function to insert into the information flow
Control to INFOSEC	C	INFOSEC control parameters
Control to IO	I	Control information for the IO function to insert into the information flow
Control to IO	C	IO control parameters
Control to Environment Adaptation	I	Control status, statistics
Control to Environment Adaptation	C	Environment adaptation control parameters
Control to User	I	Information parsed from the received information stream
Control to User	C	Display of operating status
Control to Remote Control	C	Status
Environment Adaptation to Antenna	C	Antenna control parameters
Environment Adaptation to RF	C	RF control parameters
Environment Adaptation to Modem	C	Modem control parameters
Environment Adaptation to INFOSEC	C	INFOSEC control parameters
Environment Adaptation to IO	C	IO control parameters
Environment Adaptation to Control	I	Information for the Control function to pass along to other functions to insert into the information stream
Environment Adaptation to Control	C	Control parameter inputs
Environment Adaptation to User	I	Statistics
Environment Adaptation to User	C	Status
User to IO	I	Multimedia information
User to IO	C	Flow control
User to Secure IO	I	Keys
User to Secure IO	C	Secure control parameters, front panel keyboard
User to Control	I	Information to insert into the information stream
User to Control	C	Keypad, Radio control parameters
User to Environment Adaptation	I	Information to insert into the information stream
User to Environment Adaptation	C	Environment adaptation parameters
Antenna	Au	Interface to share information between antenna functions for co-site interference mitigation, etc.
RF	Au	Interface to share information between RF functions for coordination of multi-channel operation
Modem	Au	Interface to share information between Modem functions for coordination of multi-channel operation
Control	Au	Interface to share information between Control functions for coordination of multiple radio system operation
Environment Adaptation	Au	Interface to share information between environment adaptation functions for coordination of multi-channel operation
User	Au	Interface to accommodate multiple user control (local, remote)

Interface	Transfer Type	Example Content
Wireside to IO		Standard wire side interfaces for data, voice, LAN and multimedia
Fill Device to Secure IO		Standard fill device interface
Remote Control to Control	C	Control parameters

3.2 Architecture Model

An architecture is the culmination of using as the basis for the design, construction, modification and the operation of a product derived from the design principles, physical configuration, functional organization, operational procedures, and data formats. This section, in three separate subsections, will develop the mapping and modeling from the generalized MMITS architecture to the next level of definition for handheld and mobile units as well as identify the existing standards that would be affected by the MMITS approach and offer suggested extensions to the existing standards for accommodating the operation within those environments.

Table 3.2-1 displays the differences between "Handheld" and "Mobile" systems. Besides form factor and power/performance constraint differences, the most striking difference is that, with

Table 3.2-1 MMITS Differences between Handheld and Mobile/Stationary Systems

CRITERIA APPLICATIONS	Handheld Single standard environment	Mobile/ Stationary *Multiple standard environment
Prerequisites:		
Power Consumption	Minimum	Moderate
Weight	Minimum	Moderate
Volume	Minimum	Moderate
Price	Minimum	Moderate
Resulting in:		
Receive Elements		
receiver dynamic range	Moderate	Maximum
noise level	Moderate	Minimum
sensitivity	Moderate	Maximum
out-of-band undesired signal behavior	Moderate	Minimum
in-band undesired signal behavior	Moderate	Minimum
Transmit Elements:		
amplifier nonlinearities	Moderate	Minimum
backdoor intermodulation	Moderate	Minimum

*Definition of Mobile/Stationary: Any multiple standard/terminal installation in a transportable mobile or stationary application, e.g., van, ship, aircraft, shelters, ground station, and headquarters

minor exceptions, handheld systems support a single standard, single session at a time, while mobile systems tend to have requirements for supporting multiple sessions and sometimes multiple standards simultaneously. A possible example of a minor exception in the single service/standard scenario for a handheld is the combination of a discrete paging standard and a voice standard in a single handheld.

3.2.1 Handheld Models

Figure number 3.2.1-1 is one model that can be used to describe the functional units in a handheld unit. This model has evolved from early dedicated analog baseband implementations to today's digital implementations and reflected common practice in dividing functions into subsystems. In single mode single band implementations those subsystems are dedicated to support single modulation techniques, protocols, data representations, etc. For an example of functions typically found in the different subsystems, please refer to Table 3.2.1-1 later in this section.

Figure 3.2.1-2 is an example of mapping the MMITS high level functional model described in section 3.1 to a typical single mode, single band handheld functional model. A subscriber identification module (SIM), derived from the GSM, may be included for security or privacy functionality.

The example maps a MMITS reference model into a grouping of functions. The top level view provides a handset context diagram. The bottom view shows how functionality may be hosted by the use of personality modules. Data is uploaded or downloaded through control interfaces.

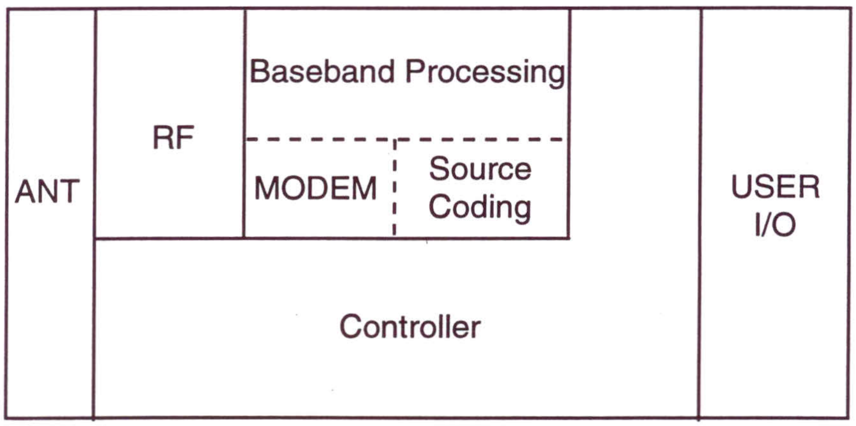


Figure 3.2.1-1 Single Band Single Mode Handheld Functional Model

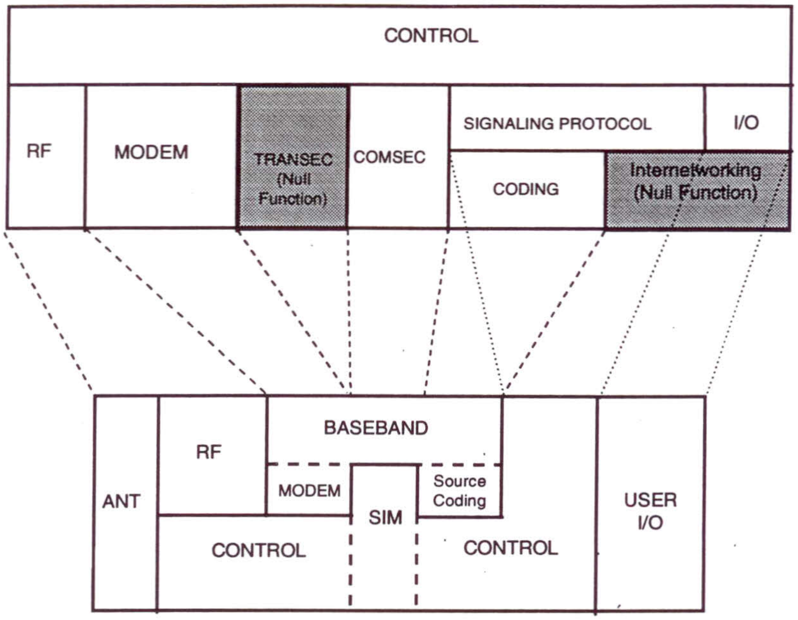


Figure 3.2.1-2 MMITS Mapping into Single Mode, Single Band Handheld Functional Model

Figure 3.2.1-3 shows a first iteration of how a typical single band, single standard model can be extended to cover multiple standards and bands using multiple devices. This view is burdened by the dedicated function approach typical of previous single standard single band implementations. An evolutionary view is shown in 3.2.1-4 where the multiple standards and bands are integrated. The user interface, in this figure, is shown as two types, a human input interface and machine interface, typically a data terminal.

In looking for a more helpful model of a software defined radio used in handheld applications, it is useful to look at a generic computer model. Figure 3.2.1-5 shows a generic computer hardware/software model.

Applying this hardware/software model to the multimode multiband extension model yields Figure 3.2.1-6. The handheld multiple service model, Figure 3.1.2-6, takes the generic handset mapping diagram, adds another level of detail, and converts it into a representation that is more computer-centric; at the bottom is a hardware layer, then a system software layer, and finally a service software layer.

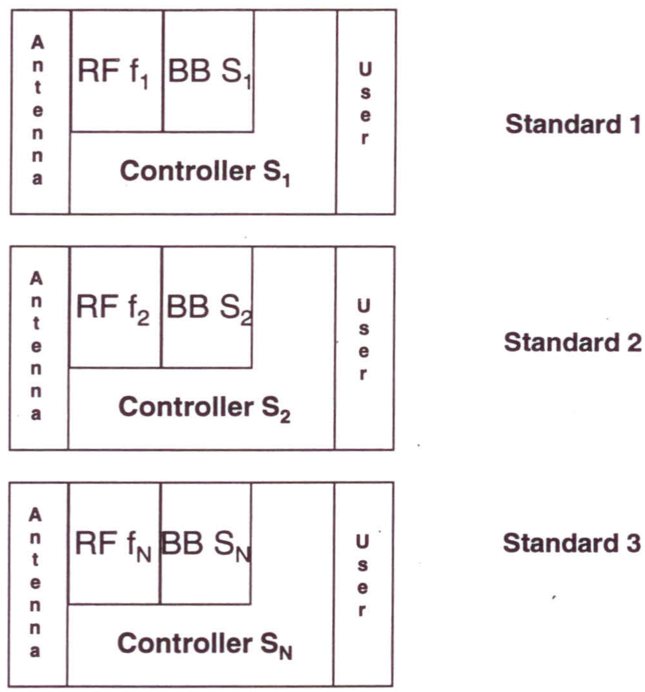


Figure 3.2.1-3 Multimode, Multiband Solution Using Multiple Single Standard Devices

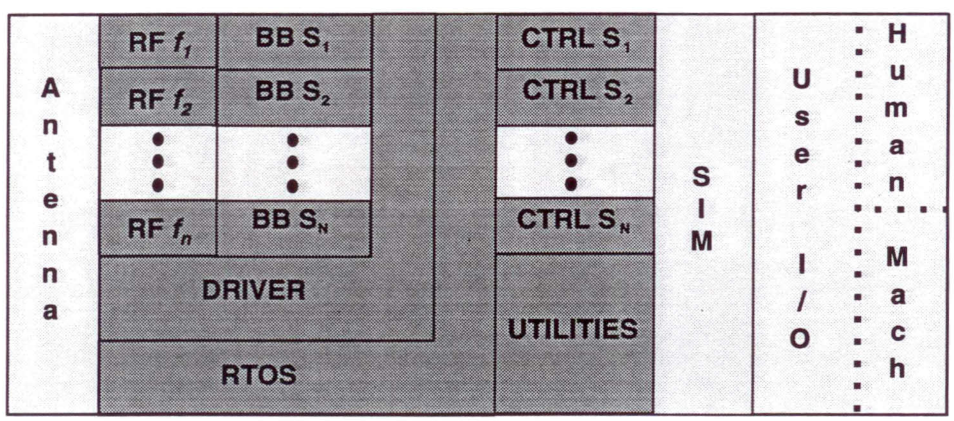


Figure 3.2.1-4 Multiband, Multimode Handheld Functional Model

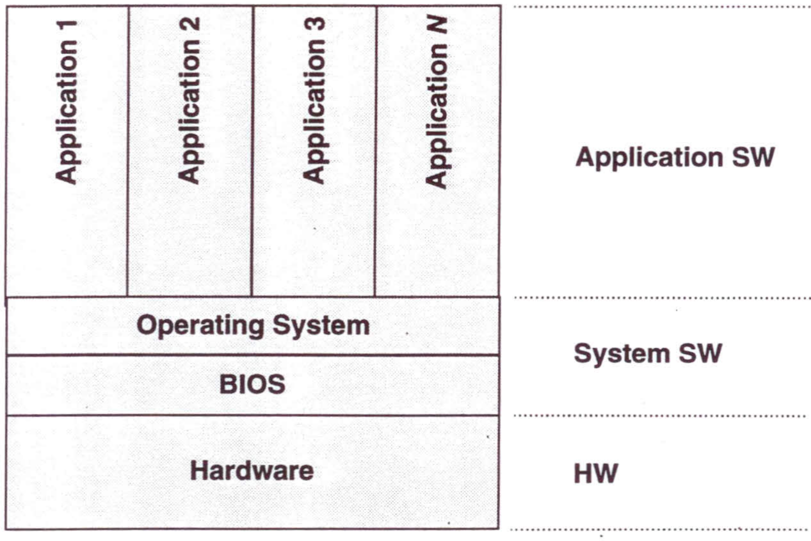


Figure 3.2.1-5 Generic PC Hardware/Software Architecture

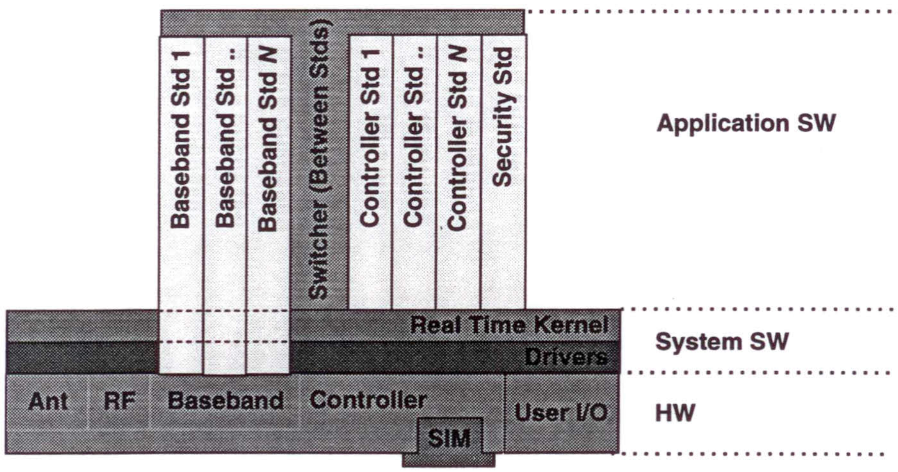


Figure 3.2.1-6 Handheld Multiple Service Model

The baseband implementations for each service are shown as cutting through the system software layer and directly interfacing the hardware layer because of the stringent performance constraints on execution speed and power consumption. A variety of technology approaches are being pursued depending on the constraints of the particular application. Battery power, size, weight and cost requirements typically push the state-of-the-art in handheld units. In order to achieve processing speed and efficiency, the majority of baseband implementation are programmed very close to the underlying hardware or logic, using low-level languages such as mircocode or assembly code. The task of switching between multiple bands using the same or different RF hardware is managed by a combination of the service switcher and the controller services for each individual operational mode.

Executing on the real time kernel (RTK) are two special service software modules: the service switcher and security services. The service switcher coordinates the selection and execution of the appropriate baseband service and controller service. It is both a peer of the baseband service and controller service modules as well as a master function supervising their execution, depending on them for support and providing control. The security services module monitors and manages the COMSEC and TRANSEC security resources of the system. Security services use security configuration information contained in the SIM to enable or disable various security services. COMSEC security processing would require a routing of the data path between the source coding and channel coding functions in the baseband module through a COMSEC processing function, as pictured in Figure 3.2.1-2.

If the basic wireless communications system is combined with machine intelligence to make a portable information appliance, it is sometimes called a PDA (Personal Digital Assistant) or HPC (Handheld PC). It may be desired to combine some of the communications processing requirements with some of the information processing requirements and execute them on the shared system resources. Figure 3.2.1-7 shows how this can be accommodated in the handheld multiple service model.

NOS / OSS (network operating system / operating support system) is a 'shell' that executes on top of the RTK. It has different service requirements than the controllers. For example, it may allow more liberal interrupt policies, etc. The NOS / OSS must have a SDK (software development kit) that allows users, carriers and manufacturers as well as software developers to easily develop, field and support applications. At this time there are two notable models for this element: Netscape / Java and Microsoft Exchange / "Active X." There is a high rate of innovation in this area in the industry at this time and there may be other possible solutions for this element.

Applets provide functionality that can be resident on the handheld device, in the network, at a remote site or some combination of the above. Applets provide the user with such functionality as computer applications, computer assisted communications, intelligent agents, etc.

The handheld multiple service model can be considered a combination of logical and physical architecture representations. Due to continuous innovation, technology evolution and the small

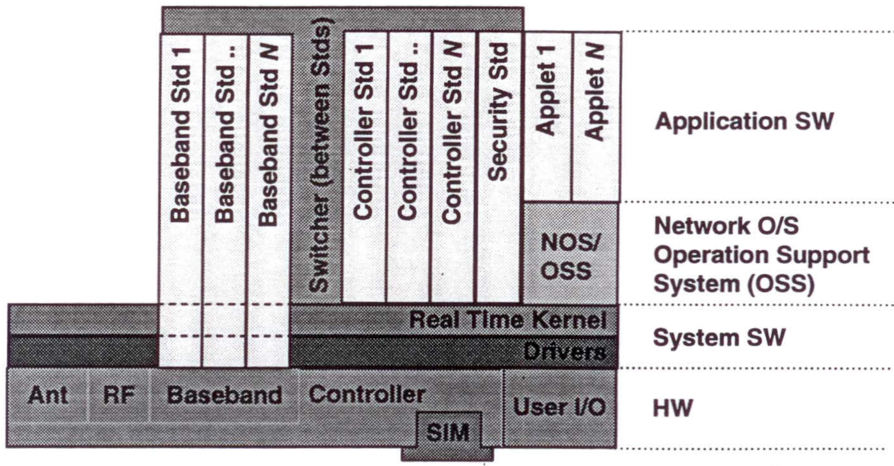


Figure 3.2.1-7 Handheld Multiple Service Model With PDA Extension

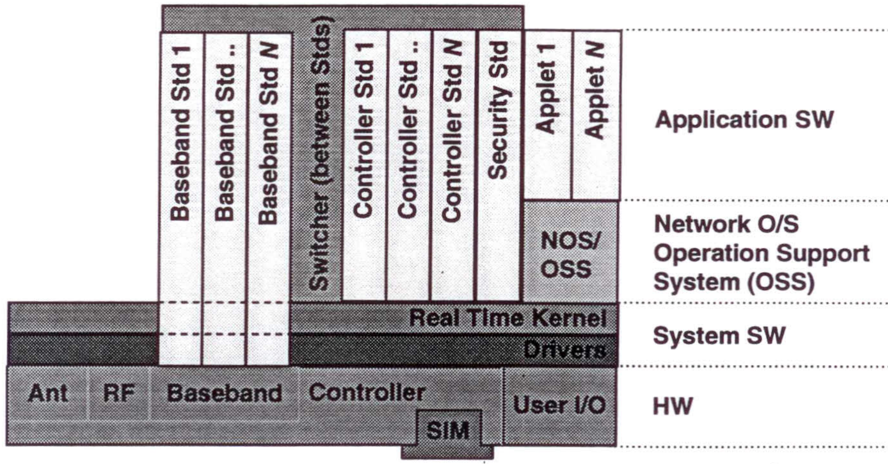
form factor driven by the various applications for handheld units, the number of stable physical interfaces are very limited. Most of the interfaces are only stable on a logical or API level.

Potential API's could be

- RTK/Service Switch
- RTK/Security Service
- Service Switch/Baseband
- Service Switch/Controller
- RTK/Driver
- Controller/RTK

Potential Physical interfaces identified:

- Antenna (passive & active) to RF
- RF to baseband
- User I/O to Local Machine
- Battery
- SIM



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