Standards and Regulatory Aspects of Wireless Local Communications

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Abstract: Over 7 different international standards bodies are developing various wireless standards. Hearings and rulemaking proceedings are taking place in the regulatory agencies in many of the industrialized nations. This paper presents an overview of the wireless standards and regulatory arenas, and attempts to clarify some of the distinctions among the emerging standards.

The international, European, and U.S. standards and regulatory organizations will be reviewed with an emphasis on how wireless LAN standards will evolve. Additionally, particular details of the Digital European Cordless Telecommunications (DECT) system, CT2, CT2+, and the emerging work of Bellcore (Universal Digital Portable Communications System) will be compared and contrasted.

1. Introduction

In the past two years the Federal Communications Commission (FCC) has received over 50 applications for experimental licenses for Personal Communication Service (PCS) trials, as well as related petitions for rulemaking (Table 1). The Canadian Department of Communications has authorized 11 similar trials. The European Commission (EC) and the UK have gone further and allocated frequencies on a primary basis to specific wireless systems. The European Council of Ministers and other European nations have signed a memorandum of understanding setting aside the band 1880 to 1900 MHz on a primary basis for DECT[1], 864-868 MHz for CT2, and 890-915 MHz and 935-960 MHz for GSM (1800-1860 for the UK's implementation of GSM).

Standards, as well as regulatory groups, are actively involved in shaping the emerging wireless systems. The international CCIR, the American ANSI, TIA, T1, Europe's ETSI, and the IEEE all have significant efforts underway to set various wireless standards.

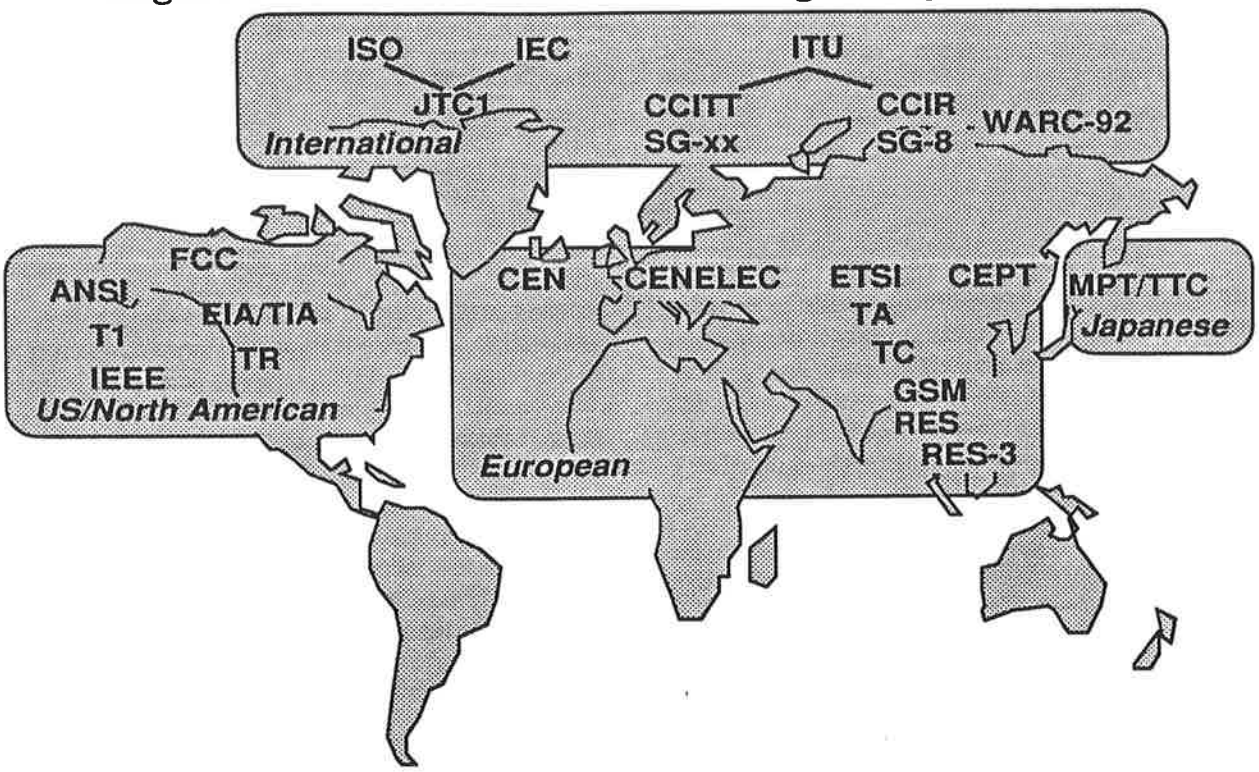
Needless to say, there is a comparably diverse array of organizations that are intending to provide some order to the chaotic wireless efforts. Principle among these, is the international CCIR (Comité Consultatif International des Radiocommunications) and the ITU (International Telecommunication Union) to which it reports. Figure 1 highlights the relevant standards and rulemaking bodies involved in wireless issues. Section 2 of this paper describes these standards bodies, their interrelationships, and their wireless efforts. Section 3 discusses the regulatory organizations and their activities. Section 4 explains the nature of some of the principle emerging standards, particularly CT2, DECT, and Bellcore's UDPCS.

2. Standards Organizations

There have been many sobering stories of well engineered products produced at good prices with willing customers that have failed because of the lack of a standard. Anyone with a Beta videotape recorder can appreciate the importance of standards. These standards efforts provide vendors with larger, less fragmented markets, the service providers with more common equipment, and the end-users benefit from a competitive marketplace. One price we pay for standards, it seems, is to be inundated with acronyms.

In some technical efforts, regulatory bodies also determine the standards to be used, particularly for the broadcast standards. For example, the U.S. HDTV standard is to be chosen by the FCC. However, the current trend in the U.S. appears to be for the regulatory bodies, and the FCC in particular, to allocate frequencies and to set interference controls but to leave the specific standards up to industry forums. For example, the FCC has allowed the cellular operators to provide service without using the analog AMPS standard.[2] Consequently, it is reasonable to consider the regulatory and standards bodies separately. This section presents an overview of the standards organizations that are active in developing wireless standards at the international level as well as in Europe and United States.

Figure 1 - Wireless Standards and Regulatory Bodies



ANSI	American National Standards Institute
CCIR	Comité Consultatif International des Radiocommunications
CCITT	Comité Consultatif International Télégraphique et Téléphonique
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electrotechnique
DECT	Digital European Cordless Telecommunications
EIA	Electronics Industry Association
ETSI	European Telecommunications Standards Institute
GSM	Global System Mobile (Groupe Spécial Mobile)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JSA	Japanese Standards Association
JTC1	Joint Technical Committee
NTIA	National Telecommunications & Information Adm.
TIA	Telecommunications Industry Association
RES3	Radio Equipment and Systems, sub-group 3
T1	Standards Committee T1 – Telecommunications
TA/TC	Technical Assembly/ Technical Committee
UDPCS	Universal Digital Portable Communications System
WARC	World Administrative Radio Conference

2.1. International

ISO / IEC

The International Organization for Standardization (ISO), founded in 1946, and the International Electrotechnical Commission (IEC) have had an important role in adopting several of the IEEE 802 standards on an international basis. The IEEE 802.2, .3, and .4 standards have been adopted as ISO/IEC 8802.2, .3, and .4 international standards. An IEEE 802.11 wireless LAN standard is also likely to come before ISO/IEC for adoption. Typically, ISO has been active in computer and information technology standards but has not been active in radio issues. It remains to be seen how a Wireless LAN standard will be treated by ISO.

The scope of the IEC is the development of international standards for electrotechnology while the ISO's includes everything *not* covered by the IEC. In recognition of the technical overlap that takes place in the Information Technology field, these two organizations formed a Joint Technical Committee, JTC1. Interestingly, the American ANSI is the world secretariat for JTC1, but the administrative work for the technical advisory groups within each

member nation is spread throughout several organizations, including the IEEE. Consequently, the development of an IEEE 802.11 Wireless LAN standard will ultimately pass through the TJC1 approval process.[3]

2.2. United States Standards Bodies

In the United States, the American National Standards Institute (ANSI) serves to coordinate and accredit many of the U.S. standards organizations. It does not write standards but reviews the procedures by which accredited committees produce standards, and represents these standards development organizations in the international bodies such as ISO. It gets most of its funding from private companies and member standards bodies. The relevant standards bodies working on wireless under the ANSI umbrella are the IEEE, EIA, and the Standards Committee T1. "T1" is composed predominantly of Common Carriers and Local Exchange Carriers and is sponsored by the Exchange Carriers Standards Association. However, T1 is an open forum with organizational membership. The Committee T1 consists of technical subcommittees T1E1 concerned with Network interfaces; T1M1 Maintenance; T1Q1 Performance; T1S1 Services Architecture, Signalling, ISDN Access, and SS7; T1Y1 Speech Coding, and T1X1 for network to network interfaces. Several of these subcommittees have an interest in wireless access.

In mid 1990 COMSAT proposed to T1E1 the creation of a new project concerning mobile to PSTN interfaces. The T1 Administrative Group, recognizing the complexity and scope of the project formed T1P1 to coordinate and oversee the standardization of Universal Personal Telecommunications (UPT) and wireless access in particular. It met for the first time in December 1990 and has just recently established its own structure *vis.*:

- T1P1.1 program management and standards planning
- T1P1.2 system engineering for wireless access and terminal mobility
- T1P1.3 systems engineering for Personal Communications Service (PCS) and network aspects

In addition to coordinating the standardization process, the mission and scope of T1P1 includes defining the interface specifications for wireless access to the public telephone and data networks, including the PSTN and ISDN. Currently, T1P1 has established liaisons with CCIR US Task Group 8/1, TIA, and IEEE 802.11.

IEEE

Although strictly international in membership, the IEEE standards activities have been predominantly driven by and viewed as a U.S. organization, hence it is accredited by ANSI. In the case of the IEEE 802.11 wireless LAN working group, the chair and a substantial part of the membership are from outside the US but it has only filed comments with the US FCC and no other nation's regulators. It has a liaison with T1P1, and with ETSI/RES-3.

This802.11 group has set for itself the task of defining a common air interface for wireless LANs operating in the 1 to 50 Mbit/s range with the possibility of several distinct physical layer definitions running at different data rates. A major decision for this group is the question of voice/data versus data-only support, following the 802.9 standards work on a voice/data LAN. Data-only supporters are concerned that the standard not be overburdened with voice capabilities, while others see a need for voice-like isochronous data for control automation applications, as well as interactive voice applications.

EIA/TIA

The Electronic Industries Association (EIA) working together with the Telecommunications Industry Association (TIA) has been the principle organization responsible for American cellular telephone standards. This has included the AMPS (IS-3) standard as well as the new Dual-Mode (IS-54) digital system. Active groups within EIA/TIA working on Technical Requirements (TRs) include: TR-8 for Land Mobile Service, TR-45.1 continuing work on Analog Terminal Interface Standards, in particular, the Advanced Mobile Phone System (AMPS), TR 45.2 Intersystem standards (Mobile Application Part, MAP), and TR 45.3 Subcommittee on Digital Cellular Systems.

In 1987 the Electronics Industries Association (EIA) filed a petition for rule making seeking a permanent allocation for cordless telephones in the 800/900 MHz band. Finding that an allocation in that portion of the spectrum for cordless telephones was not justified, the Commission denied EIA's proposal on November 19, 1989[4], and made the 46/49 MHz allocation permanent.

2.3. European Standards Bodies

CEN / Cenelec

About 20 years ago, while "Europe-92" was a wistful dream, separate European national standards organizations recognized the need for a European standards body to parallel the international standards bodies. The European Committee for Standardization (CEN) was formed for non-electrical products and parallels the ISO, while the

European Committee for Electrotechnical Standardization (Cenelec) complements the IEC. The national standards bodies that comprise CEN and Cenelec - from the 12 European Commission (EC) countries as well as six European Free Trade Association (EFTA) countries - are obligated to adopt the CEN/Cenelec standards. CEN and Cenelec like CEPT, the Conference of European Posts and Telecommunications Administrations, have apparently not been an efficient body for responding to the rapid changes in telecommunications. The European Commission has taken a firmer role in creating a stronger set of European standards bodies such as ETSI.

ETSI

Because of difficulties with network operators, Cenelec had been unable to make much headway in the area of telecommunications standards, which the twelve member nations recognized would be crucial to the success of a single market. Consequently, the EC established the European Telecommunications Standards Institute (ETSI) in 1988 to complement the CCITT, the international group that develops telecommunications standards.

ETSI is comprised of organizational members (as opposed to individual membership as in IEEE) with a significant membership fee required. Its membership is limited to European based organizations and European operations of multinational corporations. It currently consists of approximately 94 manufacturers, 43 administrations, 18 user organizations, 2 private service operators, and 3 research bodies from the 12 EC countries, the six EFTA countries, and Cyprus, Malta, and Turkey.[5] There are also more than 20 officially accredited observers, including the U.S. State Department and the Japanese Trade Association.

Since its formation by the EC in 1988, this organization has been extraordinarily active and has been responsible for adopting the United Kingdom's specification for CT2[6,7], over the objections of the EC's directorate. ETSI has also advanced the Global System Mobile (GSM) specifications[8], the Digital European Cordless Telecommunications system (DECT)[9], as well as the European Radio Messaging System (ERMES) for pan-European paging. ETSI is also considering a common dedicated mobile data air interface standard.[10]

The Global System Mobile (GSM), was previously established by the CEPT but moved to ETSI. It is a broadranging pan-European digital cellular system which specifies everything from the handset keyboard interface to the signalling between switching centers. It parallels the TR45 cellular radiotelephone group in TIA.

The RES-3 sub technical committee has recently adopted the CT2 specification[11], and also has responsibility for the DECT standard. This sub technical committee is composed of about 56 participating organizations and is supported by paid staff (PT-10) that has at least 50 staff months allocated in 1991. This effort is expected to yield a 900 page specification for DECT by early 1992.

A new group, NA7, has been formed on Universal Personal Telecommunications (UPT) to lay out a work program in Spring of 1991.

2.4 Japan's TTC and JSA

In mid 1989, the Japanese Ministry of Posts and Telecommunications (MPT) completed specification of a digital mobile telephone system and submitted it to the Telecommunication Technology Council (TTC). In order to reduce friction with the U.S., this development included sharing specifications with a U.S. trade delegation. The Radio System Development Center (RSDC), set up by electronic equipment makers and others, helped develop this system that is designed to work well in outdoor environments. This system is planned for commercial introduction by the spring of 1992.

The Japanese Standards Association (JSA) is also reportedly active in developing and promoting both a Universal Digital Cellular (UDC) system standard and an Advanced Cordless (DECT-like) system.

3. Regulatory Activities

3.1. ITU (International Telecommunication Union)

Dating back to 1865 (as the International Telegraph Union), the ITU is currently an agency of the United Nations. The ITU has divided the world into three geographic regions where localization of the rules apply (Europe in region 1, the U.S. in 2, Asia in 3). The increased mobility of radio units integrated with laptop computers and pocket phones may present new challenges to this regional approach to allocations.

The organization of the ITU includes: (1) the Plenipotentiary Conference, which is the supreme organ of the ITU and meets approximately every five years; (2) two World Administrative Conferences, one for telegraph and telephone and one for radio (WARC) which meets as needed, (3) the Administrative Council, which meets annually and is responsible for executing decisions of the Plenipotenti-

ary Conference; (4) the General Secretariat, responsible for administrative and financial services; (5) the International Frequency Registration Board, concerned with the assignment of radio frequencies; (6) the International Telegraph and Telephone Consultative Committee (CCITT); and (7) the International Radio Consultative Committee (CCIR), which conducts technical studies in the radio field.[12]

A recent ITU Plenipotentiary Conference (Nice, 1989) resolved that a World Administrative Radio Conference (WARC) shall take place in the first quarter of 1992 for dealing with frequency allocations in certain parts of the spectrum, particularly the mobile radio allocations and the Future Public Land Mobile Telecommunications Systems (FPLMTS). This "WARC-92" conference is scheduled for Feb. 3 - March 5, 1992 in Malaga, Spain. Such general WARCs are rare, with the last one held in 1979. So far the FCC has issued three notices of inquiry concerning agenda items for this conference, and the state department has held formal discussions with other national regulators to coordinate WARC contributions.

This conference should produce a draft watershed treaty calling for the allocation of spectrum for FPLMTS as well as other blocks of spectrum for Low Earth Orbit Mobile Satellite Services and high definition TV satellite broadcast. It generally takes several years for the signatory nations to ratify the treaty and to implement the revised Radio Rules through national rulemaking procedures.

CCIR (International Radio Consultative Committee)

CCIR Study Group 8 studies technical and operating aspects relating to all the mobile services, radiolocation, amateur, and their satellite services. In 1985 CCIR Study Group 8 formed a special international group to identify the requirements for FPLMTS. This Interim Working Party IWP8/13 is composed of approximately 40 administrations and international organizations. At the CCIR Plenary in May 1990, CCIR Study Group 8 was reorganized and IWP8/13 was renamed as Task Group TG8/1.[13,14]

This group, in preparing a thorough analysis of FPLMTS, has estimated the total spectral requirements for universal services, both for private intra-premises and public outdoor application, at 230 MHz, with 60 MHz for the exclusive use of low power personal communications services. This estimate was based upon an exclusive allocation with no sharing with alternative service providers. Such sharing would inevitably increase the spectral requirements of such a system. Recently, a new Question (AM/8) was adopted by TG 8/1 to initiate studies concerning radio local area networks.

CCITT (International Telegraph and Telephone Consultative Committee)

CCITT Study Group XVIII has developed a baseline document concerning Universal Personal Telecommunications (UPT). This document recommends that specific Study Groups develop recommendations that will facilitate mobile services. In the past they have been active in such areas as numbering plans, location registration in ISDN networks and system signalling 7 (SS7) protocols, X.400 email, and X.25 type packet-switched network standards that will likely be used for such things as visitor location registrations and authorization.

These Study Groups have the following charters: SG I: Service Definition; SG II: Network Operations; SG III: Charging and Accounting Principles; SG IV: Maintenance; SG VIII: Terminals; SG XI: Signaling architecture, MSAP (Mobility Services Application Part), SS7; SG XV: Transmission; and SG XVIII: ISDN, network architecture.

For privately owned, local area networks, the CCITT will likely not have a significant role in the standardization of the network hardware. Rather the CCITT will address the logical level of the data content, i.e. the X.400 email standards and the packet formatting of X.25, and ISDN.

3.2. U.S. Regulatory Activities

In the United States, the Congress, the FCC and the Department of Commerce's National Telecommunications and Information Administration (NTIA) are actively involved in wireless rulemaking. House Resolution 531 (the so-called "Dingell Bill" from Rep. John Dingell, D-Mich.), and Senate Bill 218, "Emerging Telecommunications Act of 1990" both call for the Department of Commerce and the FCC to reallocate, from government use to commercial use a minimum of 200 MHz located below 5 GHz. The bills call for identifying the spectrum within 2 years and making it available for commercial use in two stages, the first within 4 years of the enactment of the bill. The second part of the reallocation is to take not less than 10 years to allocate - as a reserve. In the 1990 congressional session, the bill passed the House but failed in the Senate.

The FCC, too, has been active in issuing Notices of Inquiries (NOIs) concerning PCS and the WARC conven-

tion, and dealing with various petitions for specific allocations, as shown in Table 1. The commission received over 100 comments to its PCS NOI, many recommending reallocation of the 1,880 - 1,990 MHz band for PCS. PCN America, Inc. has petitioned the FCC to allocate frequencies in the 1,700-2,300 MHz range. The FCC expressed that, "it is anticipated that the 1992 WARC will consider allocating spectrum in the 1700 MHz to 2300 MHz band for PCNs in Region 1 and possibly will address a similar allocation for the other Regions as well. The 1992 WARC may even consider providing a worldwide allocation for PCSs in this portion of the spectrum."[15] In preparing for WARC-92, the Commission has indicated that it does not feel that a common world-wide allocation is needed but that some compatibility (perhaps by having nearby bands) would be desirable. Industry comments have been mixed on this issue. Apple Computer Inc. has specifically requested an international allocation for "Data-PCS".[16] Currently, the 1880 MHz to 1990 MHz band is licensed to more than 8,100 non-government fixed service users, particularly point-to-point microwave users such as railroads, power, petroleum, and common carriers. Some of these users are converting these facilities over to fiber optic cables — contributing to making this an attractive band to request allocations in.

Of equal interest, Janice Obuchowski, Assistant Secretary for Communications and Information for the Department of Commerce, and Administrator of the National Telecommunications and Information Administration (NTIA), advocates market-based spectrum allocation.[17] This refers to an alternative to lottery and comparative hearings as a way to select licensees, perhaps even as a way to allocate the services associated with a frequency band. Under this scheme, a license would confer some property rights that could be bought and sold. As described, this scheme is not currently provided for in law (currently, radio licenses may not be sold even though a company that holds a license may, subject to FCC authorization.) Even so, the current Federal budget includes a line item for income from the auctioning of spectrum. The original version of the "Emerging Telecommunications Act of 1989" specifically forbade the auctioning of spectrum but the current drafts do not. A recent NTIA report[18] recommends the adoption of these auctions as a way for the federal government to sell spectrum and let the marketplace place a value on the real worth of a band. It could also provide an incentive for various Federal agencies to release spectrum for private use. The NTIA has estimated that the aggregate spectrum value to cellular license holders is between $46B and $80B.[17]

4. Specific Standards

CT2

The U.K. has been most aggressive in introducing new wireless systems – typically without waiting for international standardization. CT2 (cordless telephone–second generation) is one such British initiative, launched commercially in September 1989 – a full year before standardization by ETSI. A conflict arose within ETSI in 1990 over whether CT2 was to be made an interim standard or skipped entirely in lieu of the forthcoming DECT standard. The issue had to be elevated to the ETSI Technical Assembly for a decision where it was decided to make CT2 an interim standard.

This cordless phone standard is the most developed of the emerging digital phone systems. Currently there are several British manufacturers that produce "CT2" phones and full compliance with the Common Air Interface that insures inter-operability is scheduled for later this year.

Table 2 details the technical characteristics of the various proposed standards as they are known today. As indicated in Table 2, the distinctive feature of CT2 is that there is only one voice channel per RF carrier. Time Division Duplexing (TDD) is used to "ping-pong" between transmit and receive so that a base station with antenna diversity can infer the mobile unit's received signal strength over the reciprocal channel. The TDD then helps reduce the cost and complexity of the mobile unit. However, by allocating a single voice server to the radio channel (no TDMA) there is no provision for bandwidth on demand or variable data rate applications. Also, as improvements are made to voice coders this CT2 system will have difficulty taking advantage of them. No more or less than 32 kbits/s are supported. Moderate-speed voiceband modems can work over CT2's ADPCM codec but a 32 kbits/s pure digital channel could be supported if the A/D and D/A converters and codec are bypassed.

CT2+

In recent comments to the FCC[19], Northern Telecom Inc. proposed a Personal Communications Interface (PCI), commonly known as CT2+, that enhances the CT2 system. The enhancements to CT2 include additional frequency channels in the 930-931 and 902-928 MHz (ISM band) ranges, as well as the 900-959.95 MHz band where sharing agreements with fixed services permit. The enhancements also include a more efficient control channel scheme that is more appropriate given the increase in the number of channels, support for handoffs, and registration for two way calling in a visited location.

With these enhancements, CT2+ becomes an impressive wireless system that has the virtues of simplicity and availability while still providing many of the same functions of the more advanced TDMA systems. It is doubtful that ETSI will reconsider CT2 specifications but the T1P1 or T1E1 organizations may consider aspects of CT2+ for application in North America.

It is worth noting that the CT2+ proposal allows for frequency sharing with fixed microwave services — if there are no fixed service license holders nearby to interfere with, then a CT2+ base station could be configured to use that additional spectrum in that particular territory. This should be attractive to the FCC given their interest in reuse of spectrum.

DECT

The Digital European Cordless Telecommunications (DECT) standard is nearing completion by ETSI's RES-3 Technical Committee with full approval expected late this year. This highly advanced system was initiated by Ericsson as a basis for wireless PBX, with the support and sponsorship of governments of Scandinavia (not members of the EC but members of ETSI). The EC has consistently supported the notion that Universal Personal Communication be realized through the harmonious interworking of DECT, GSM, and ERMES.

Technically, DECT is an aggressive system that multiplexes 12 voice channels (32 kbits/s, ADPCM) onto 11 frequency carriers thus providing 132 possible servers, enough for a dense office environment. In order to simplify the handset, TDD is used with the consequence that the radio channel raw data rate is an uncomfortably high 1152 kbits/s. Given multipath delay spreads in an outdoor or spacious indoor environment, this high data rate may require equalization to work well. Alternatively, antenna diversity, frequency diversity, and port diversity may compensate for the multipath fading concerns. Only field experience will tell. DECT uses dynamic channel allocation so that base stations determine what frequencies to operate on dynamically as load and adjacent base stations permit.

In order to gain field experience, Ericsson has developed a "pre-DECT" product, DCT-900, with 8 time slots operating in the 860-870 and 940-944 MHz bands. Unlike the CT2 system, DECT supports variable data rates for wireless LAN applications including BRI ISDN (Basic Rate Interface at 144 kb/sec) as well as 32 kbits/s through 736 kbits/s (23 of the 24 time slots can be assigned in one direction). (Current specifications call for a software imposed limit of 30% of the system capacity to be tied up with data transmission but it is not clear how it knows what is data versus what is voice.) It is important to remember that this data service can be provided off of a privately owned PBX or LAN server, there need be no airtime charges or end-user licensing hurdles to using this system. Both public and private base stations are envisioned. This appears to be the way moderate-speed wireless LANs are to operate in Europe.

UDPCS

After the breakup of the Bell System on January 1, 1984, part of AT&T Bell Laboratories was "spun off" to form Bell Communications Research, or Bellcore. Bellcore serves the research needs of the regulated side of the seven regional holding companies. In this capacity, Bellcore has had a longstanding research program to explore wireless loop access. This has resulted in two issuances of a framework advisory for a standard Universal Digital Portable Communication System (UDPCS).[20] These documents propose a UDPCS system and solicit industry comments. The key aspects of the currently proposed specification for UDPCS are given in Table 2. Unlike the DECT system that was developed first for indoor wireless PBX applications, the UDPCS system is optimized for operation in outdoor environments were large delay spreads are expected. In order to combat these large delay spreads, the symbol rate was reduced by using Frequency Division Duplexing (FDD instead of TDD) and 4 level modulation (QPSK). Consequently its 250 kbaud channel rate is less than 1/4 of DECT, yet it serves nearly as many lines as DECT (10 instead of 12). As with DECT, data rates from 32 kbits/s to 320 kbits/s are supported by allocating one or more time slots to a data terminal.

With many Frequency Division Duplexing systems, an expensive duplexing filter is required to filter the strong transmit signal from the weak received signal. However, the proposed UDPCS system staggers the transmit and receive timeslots so that the terminal does not need a duplexer.

Bellcore typically facilitates the development of standards by first issuing Framework Advisories such as this, then transferring the work to a standards organization such as T1 that defines the *interface* specifications. Bellcore then writes equipment requirements that include those interface specifications but also include power, size, cooling, etc.,. specifications.[21]

Bellcore can unilaterally specify the technical requirements of equipment, but typically committee T1 is used to

agree upon a specification in a multilateral way. T1P1 may be that forum for making UDPCS a standard, in fact Bellcore has been an active contributor to T1P1.

As a rule, Bellcore specifies only telephone network equipment, not the privately owned equipment such as a PBX or a LAN. However, a standard evolving out of T1P1 may be general enough to include such applications. One difficulty, however, will be the aversion to offer a tariffed service over spectrum that is shared with private systems. This will likely require that separate frequency allocations be made for public and private wireless networks, while sharing a common air interface.

Other Notable Systems

CDMA

Qualcomm Inc., together with NYNEX, Ameritech, PacTel, and AT&T have announced an alternative digital cellular system that uses spread spectrum Code Division Multiple Access (CDMA) for multiplexing different channels over a common frequency band. A trial of this system is scheduled for late this year or early 1992 in New York City. This is a proprietary system that uses the standard cellular frequency band under the provisions of FCC Report and Order, Gen. Docket No. 87-390, 65 RR 2d. 983 (1988), which allows a cellular operator to provide services that do not use current cellular standards, provided that out-of-band emissions limits are not exceeded. This system will provide standard cellular mobile phone type services but with a digital air interface that could support some low data rate metropolitan area networking applications.

WIN (Wireless Indoor Network)

Motorola Inc. has pioneered the use of the 18 GHz Digital Termination Service (DTS) bands to provide an indoor wireless LAN that operates at 15 Mbit/s and connects up to 32 Ethernet nodes via radio. This product was made possible by recent changes to the DTS rules in the FCC Report and Order, PR Docket No. 88-191, adopted Feb. 8, 1990, specifically ¶94.88. Currently another proprietary interface, this system suffers from the high propagation losses of 18 GHz. Consequently, coverage is limited to about 500 feet of the base(s). These also require licensing with the FCC, but the vendor (Motorola) can coordinate that for the customer, provided that the network is not moved out of the confines of the building.

5. Summary

The development of a Personal Communications System, for voice, data, or both, is a worldwide effort requiring coordination and cooperation among many hundreds of companies and organizations. Current FCC rules have some allowances for the emerging new products; cordless phones and wireless LANs have been available on the market now for several years. But in order to introduce a product that can truly interwork with and not against a variety of other products of different manufacturers, the standards and regulatory process must be followed. It is not a gantlet, but a process that brings together many others that can add to the value and intellectual basis of a product. Standards do not reduce competitive forces but provide a context for competition. There does not appear to be a single wireless standard emerging but rather a variety of standards from which the marketplace may choose.

There have been substantial, perhaps revolutionary, changes in the technology of wireless devices, with advanced microprocessor control and frequency agile synthesizers being cost competitive with previously less advanced systems. There have also been substantial changes in the thinking and scope of the standards and regulatory bodies. The internationalization of standards, particularly in the European arena, as well as the prospect of auctioned spectrum, are both nearly revolutionary in character and may have as profound an effect as the technological advances.

It is risky to make any predictions about what the various bodies will do, but it is doubtful that the FCC would allocate any frequencies to a Personal Communication Service that might be superseded by potential WARC-92 allocations. Consequently, it is doubtful that any permanent frequency allocation for PCS or "Data-PCS" will be made by the FCC prior to the WARC-92 deliberations. In addition, given the support that the 12 European Commission (EC) countries as well as six European Free Trade Association countries have given to PCS it can be expected that a significant allocation to PCS will come out of the WARC-92 conference, at least for Region 1. The FCC is also supportive of innovation and is anxious to insure that the U.S. does not fall behind in this area. The FCC has been encouraging experiments and products that use novel techniques such as spread spectrum to share spectrum - easing the conflicts between current license holders and new applicants. While these experimental results are not yet conclusive, the FCC and the NTIA are also exploring other, market based, approaches to contend

with these conflicts through auctions and legalized license sales.

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[18] "U.S. Spectrum Management Policy: An Agenda for the Future," NTIA Special Publication 91-23, February 1991.

[19] Northern Telecom, Response to Notice of Inquiry Relating to Establishment of New Personal Communications Services," Federal Communications Commission Docket No. 90-314, October 1, 1990.

[20] Bellcore FA-NWT-001013 "Generic Framework Criteria for Universal Digital Personal Communications Systems", issue 2, December 1990.

[21] Conversation with Gerald R. Boyer, Bellcore District Manager, Advanced Access Requirements and Systems Engineering, May 8, 1991.

Table 1 – Petitions Before the FCC Concerning PCS and Related Issues

Item	Date	Description	Frequency Band(s)
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Motorola	Report and Order, PR Docket No. 88-191, adopted Feb. 8, 1990, specifically ¶94.88.	Allows for low power indoor use of the 18 GHz band for Aries type Wireless LANs.	18.820-18.870 and 19.160-19.210 GHz

Table 2
Comparison of Various Wireless Systems

	CT2	CT2+	DECT	GSM	PCN	IS-54	AMPs (EIA-IS3)	UDPCS
Band (MHz)	864-868	930-931	1880-1900	890-915	1710-1785	824-849	824-849	.4 – 4 GHz ?
		940-941 +		935-960	1805-1880	869-894	869-894	
Bandwidth (MHz)	4 MHz	2 MHz +	20 MHz	50 MHz	150 MHz	50 MHz	50 MHz	60 MHz
Channelization	FDMA	FDMA	TDMA/FDMA	TDMA/FDMA	TDMA/FDMA	TDMA/FDMA	FDMA	TDMA/FDMA
Channel Spacing (kHz)	100 kHz	100 kHz	1.728 MHz	200 kHz	200 kHz	30 kHz	30 kHz	300-400 kHz
# of Freq. Channels	40	20 +	11	125	375	832	832	~75
Voice Ch/Freq Ch	1	1	12	8	16	3 (or 6)	1	10
Total Duplex Channels	40	20 +	132	1000	6000	2496	832	750
Duplex Method	TDD	TDD	TDD	FDD	FDD	FDD	FDD	FDD
Equiv. BW / Duplex Chan.	100 kHz	100 kHz	144 kHz	50 kHz	25 kHz	20 kHz	60 kHz	80 kHz
Channel bit rate (kbit/sec)	72	72	1152	270.833	270.833	97.2?	NA	ø50Ø
Data Service	32 kbps	32 kbps	32-736 kbps	16 kbit/s	8 kbit/s	8 kbit/s	Voiceband only	32 to 320 kbps
Speech coder	ADPCM	ADPCM	ADPCM	RPE-LTP	RPE-LTP	VSELP	NA	ADPCM
Bit rate	32 kBPS	32 kBPS	32 kBPS	13 kbps	6.7 kbps	8 kbps	NA	32 kbps
Frame Time (mSec)	2 mSec	2 mSec	10 mSec	4.6 mSec	4.6 mSec	40 mSec	NA	2 mSec
Modulation	GMSK	GMSK	GMSK	GMSK	GMSK	π/4 DQPSK	Analog FM	DQPSK
Voice & Data	~no	~some	yes	yes	yes	yes?	~no	yes
Ave xmit power (Watts)	5 mW	5 mW	10 mW	2, 5 MS	2, 5 MS	0.6, 1.2, 3.0	0.6, 1.2, 3.0	400-800mW down
Peak Transmit Power (W)	10 mW	10 mW	250 mW	8, 20 MOB	8, 20 MOB	0.6, 1.2, 3.0	0.6, 1.2, 3.0	100-200 mW uplink
Handoff ?	no	yes	yes	yes	yes	yes	yes	
Cell Radius	41-140 m	40-140 m	40 - 140 m	1 - 5 miles	0.4 - 5 miles	30 miles ?	30 miles ?	2000 feet
Availability	1989	1991	1992	1991?	1993	Late 1991	1983	1994?

CT2 from MPT 1375 "Common Air Interface Specification" 1990.
CT2+ from Response to FCC Docket No.90-314, October 1990, Northern Telecom.
GSM from Interim European Telecommunication Standard, ETSI Draft pri-ETS 300 xxx, May 1990.
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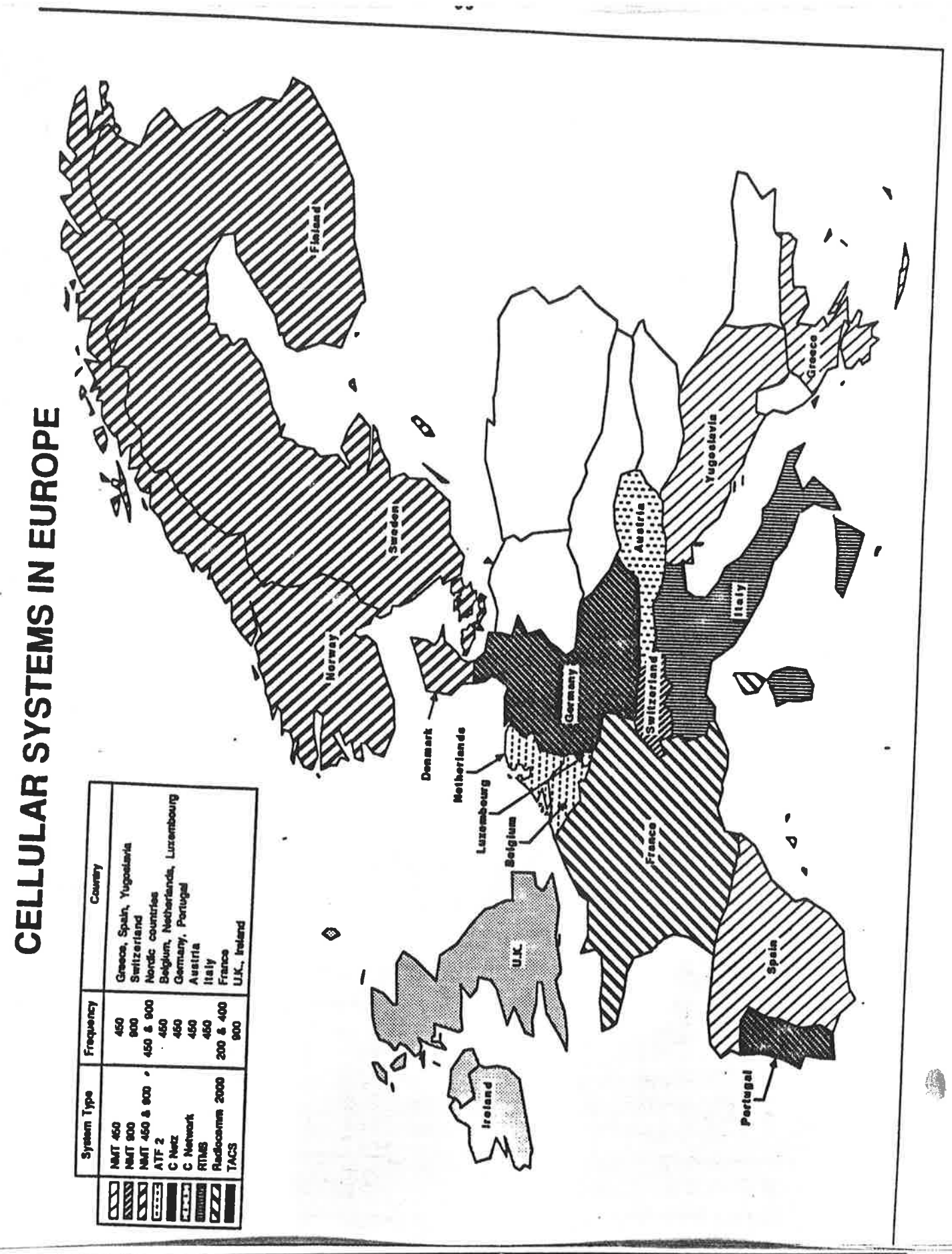
STANDARDS AND REGULATORY ASPECTS OF WIRELESS LOCAL COMMUNICATIONS

IEEE Workshop on Wireless Local Area Networks at the Worcester Polytechnic Institute

May 9, 1991

Stephen A. Wilkus
AT&T Bell Laboratories

AT&T


CELLULAR SYSTEMS IN EUROPE
System Type
Frequency
Country
NMT 450
450
Greece, Spain, Yugoslavia
NMT 900
900
Switzerland
NMT 450 & 900
450 & 900
Nordic countries
ATF 2
450
Belgium, Netherlands, Luxembourg
C Netz
450
Germany, Portugal
C Network
450
Austria
RTMS
450
Italy
Radiocoms 2000
200 & 400
France
TACS
900
U.K., Ireland
Finland
Norway
Sweden
Denmark
Netherlands
Luxembourg
Belgium
Germany
Austria
Switzerland
Italy
Yugoslavia
Greece
France
U.K.
Ireland
Spain
Portugal

Standards and Regulatory Aspects of Wireless Local Communications

- Standards Bodies
- Regulatory Bodies
- Emerging Wireless Standards
  - CT2/CT2+
  - DECT
  - UDPCS
- Wireless Futures

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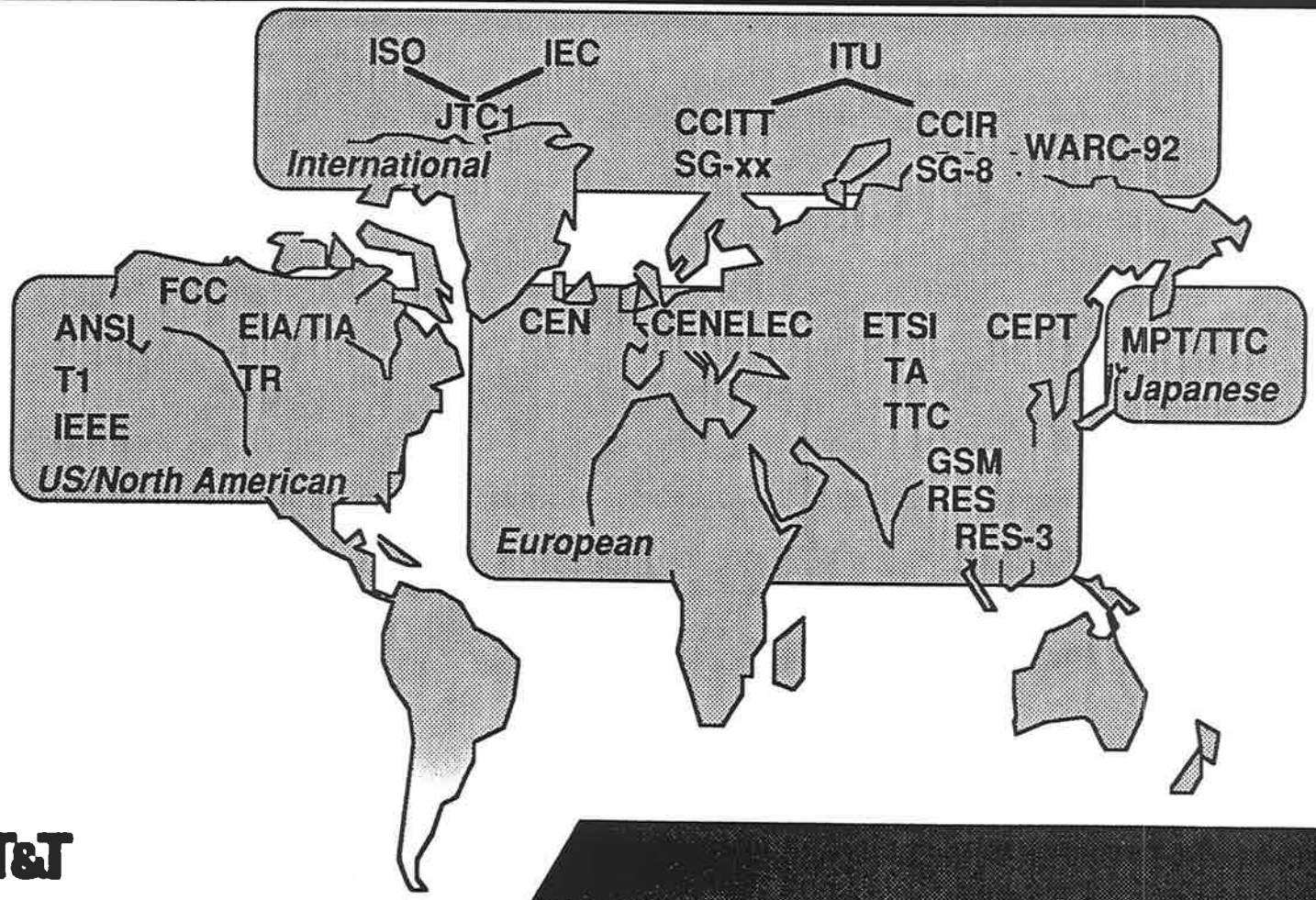
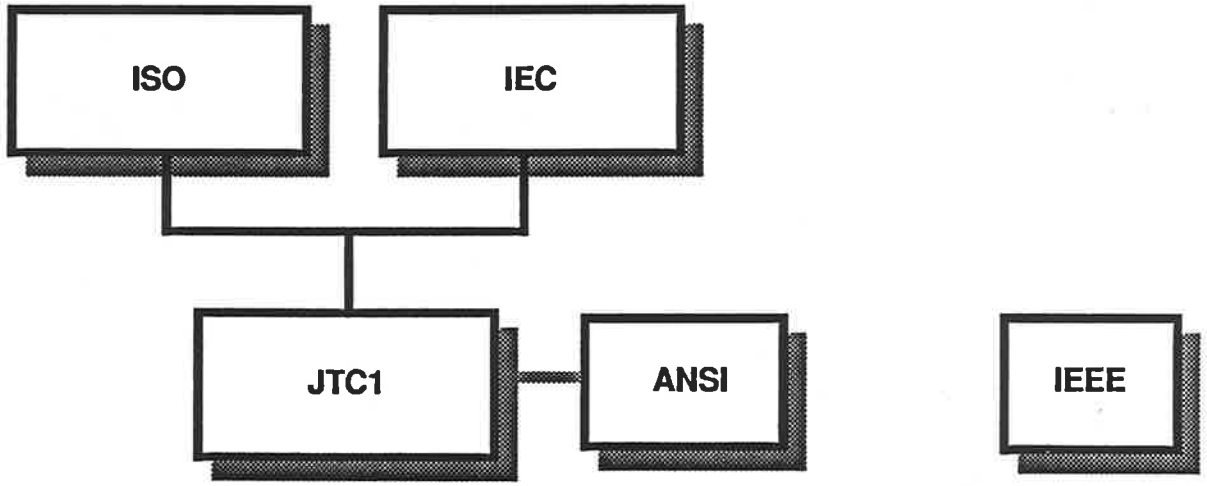
Wireless Standards and Regulatory Bodies



International Standards Bodies



ISO International Standards Organization

IEC International Electrotechnical Commission

ANSI American National Standards Institute

IEEE Institute of Electrical and Electronic Engineers

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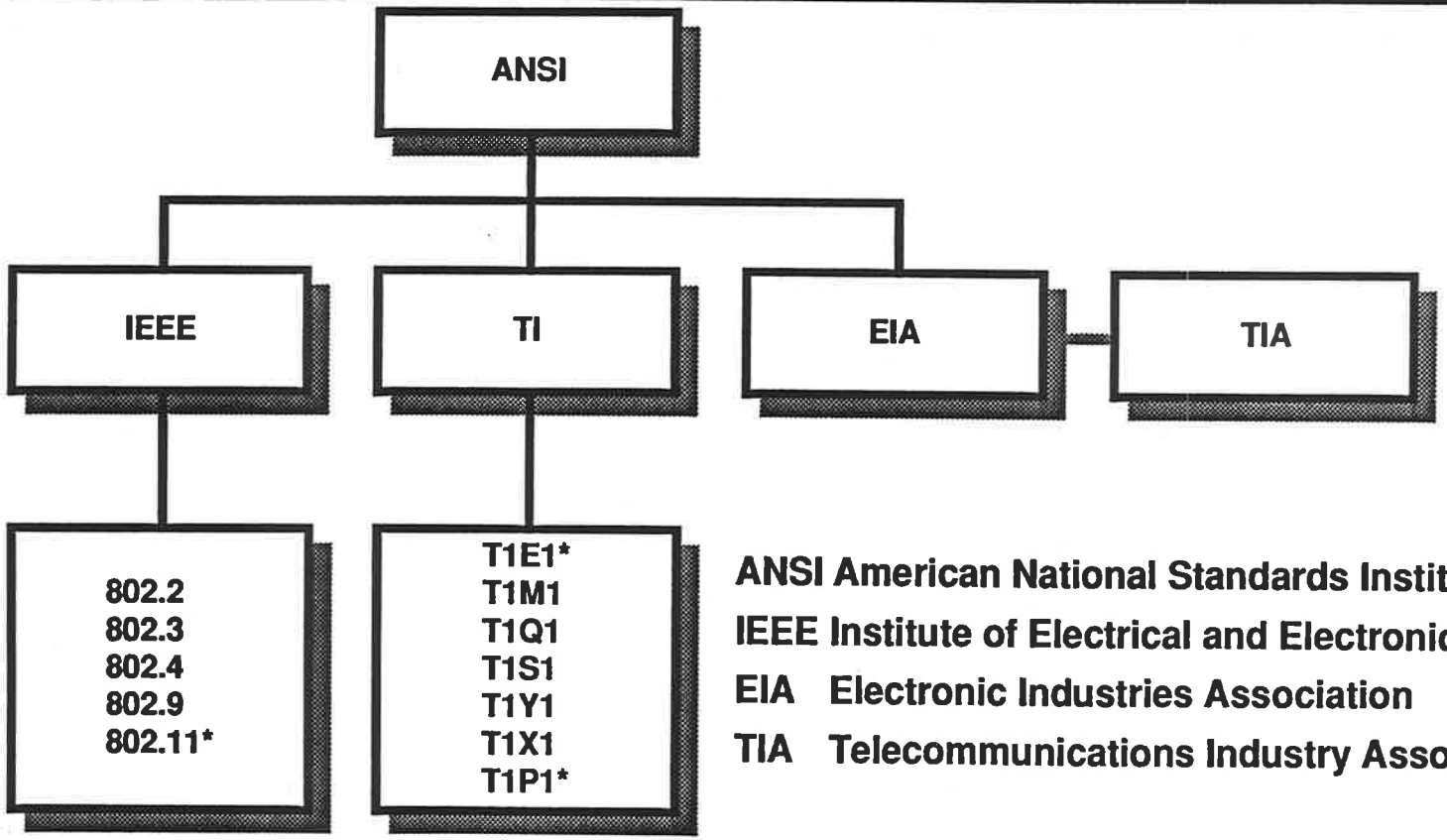
United States Standards Bodies



ANSI American National Standards Institute

IEEE Institute of Electrical and Electronic Engineers

EIA Electronic Industries Association

TIA Telecommunications Industry Association

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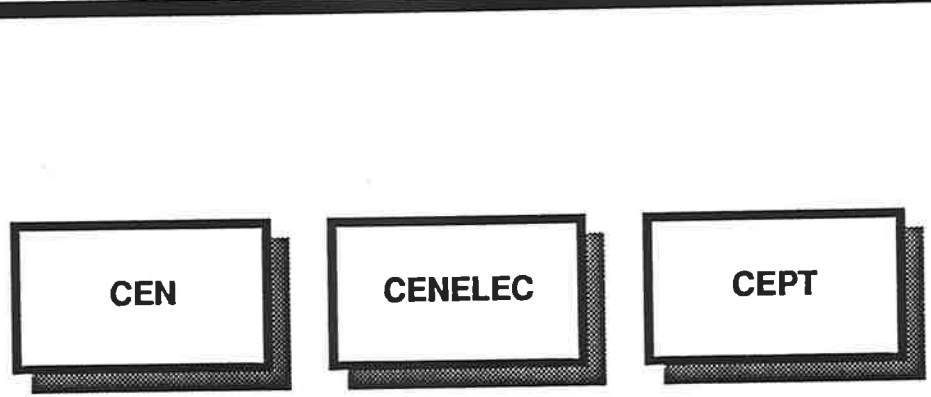
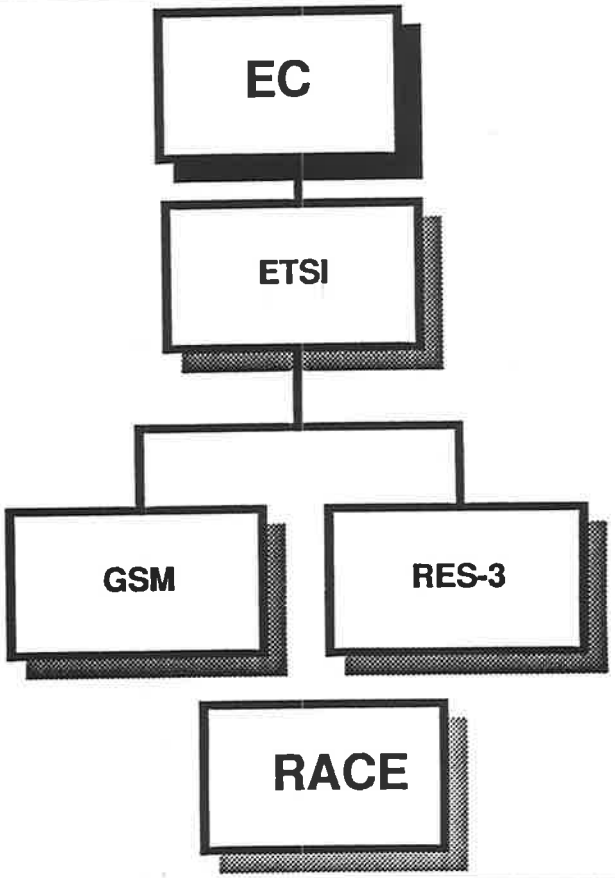
European Standards Bodies





EC	European Commission
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CEPT	Conference of European Posts and Telecommunications Administrations
ETSI	European Telecommunications Standards Institute
GSM	Global System Mobile (Group Speciale Mobile)
RES3	Radio Experts — System 3
ERMES	European Radio Messaging System
RACE	R&D in Advanced Communications — Europe

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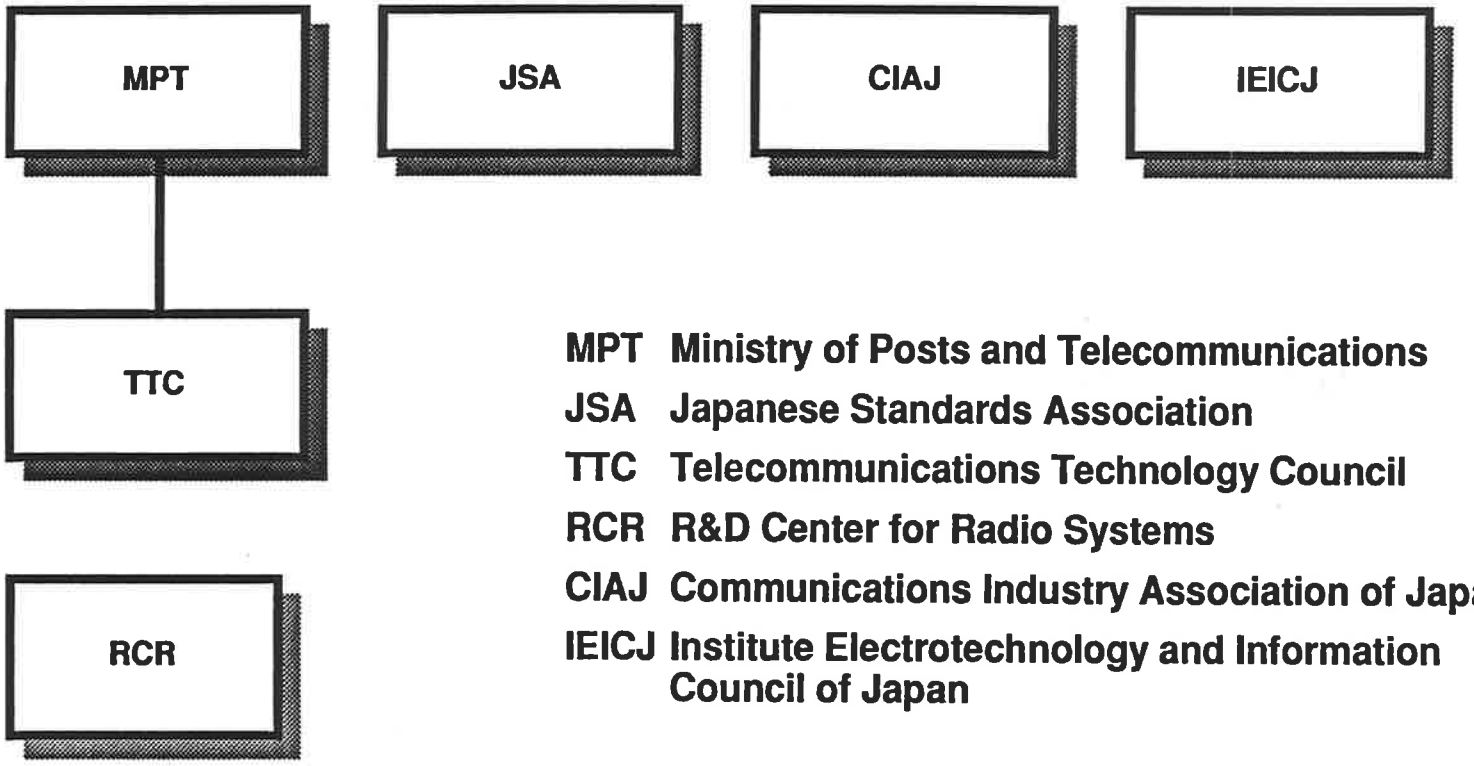
Japanese Standards Bodies



MPT Ministry of Posts and Telecommunications
JSA Japanese Standards Association
TTC Telecommunications Technology Council
RCR R&D Center for Radio Systems
CIAJ Communications Industry Association of Japan
IEICJ Institute Electrotechnology and Information Council of Japan

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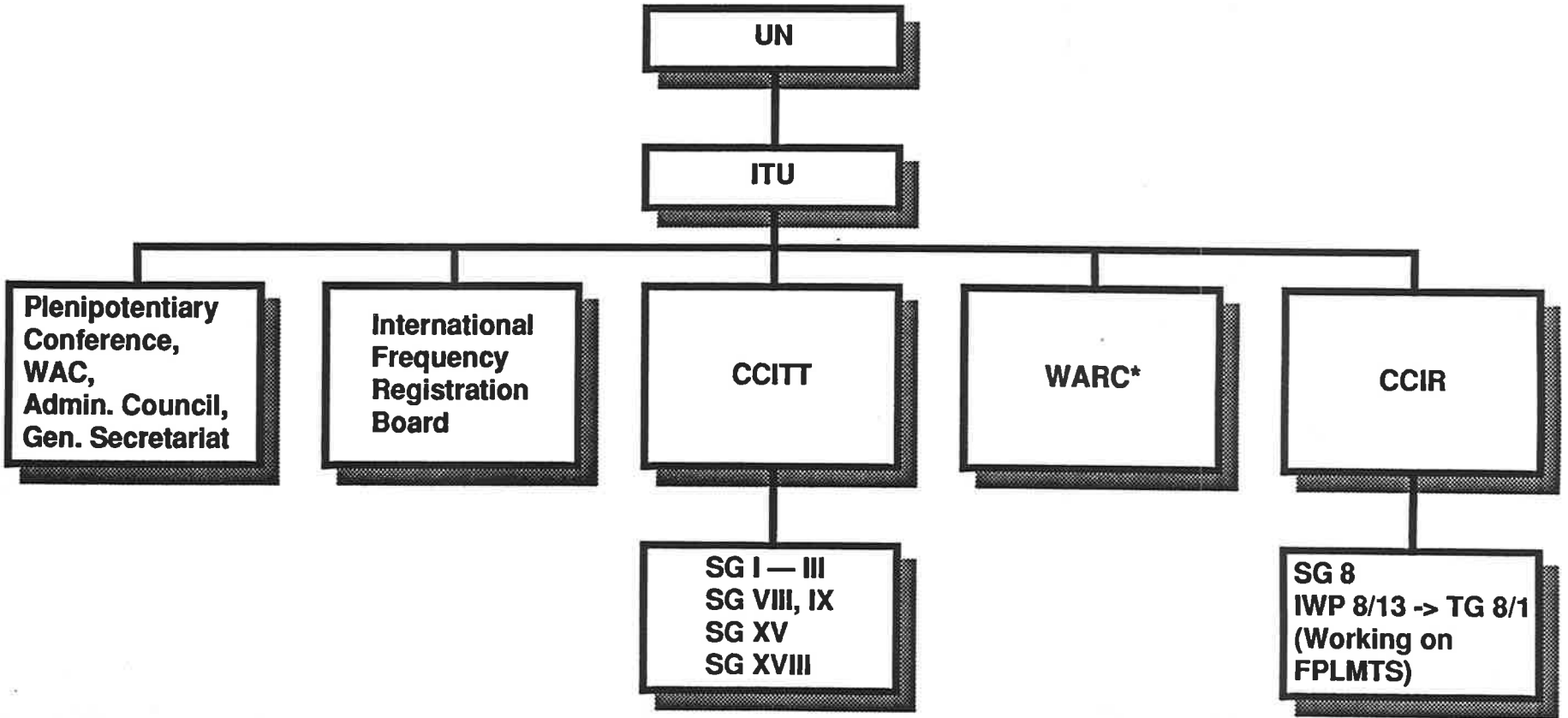

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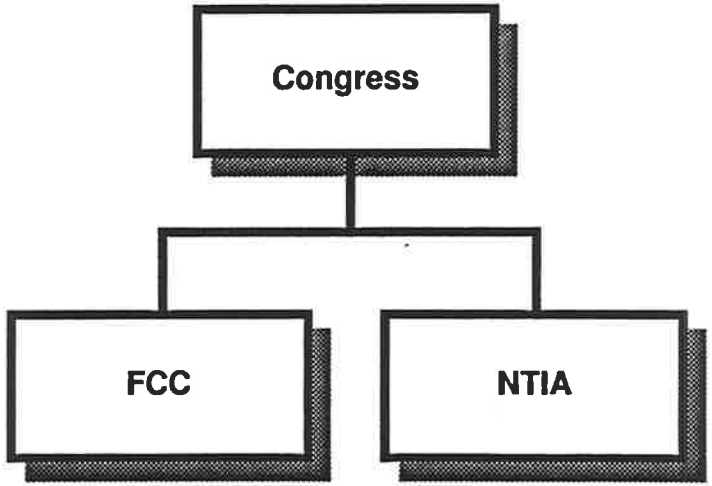
United States Regulatory Bodies



FCC Federal Communications Commission

NTIA National Telecommunications and Information Administrations

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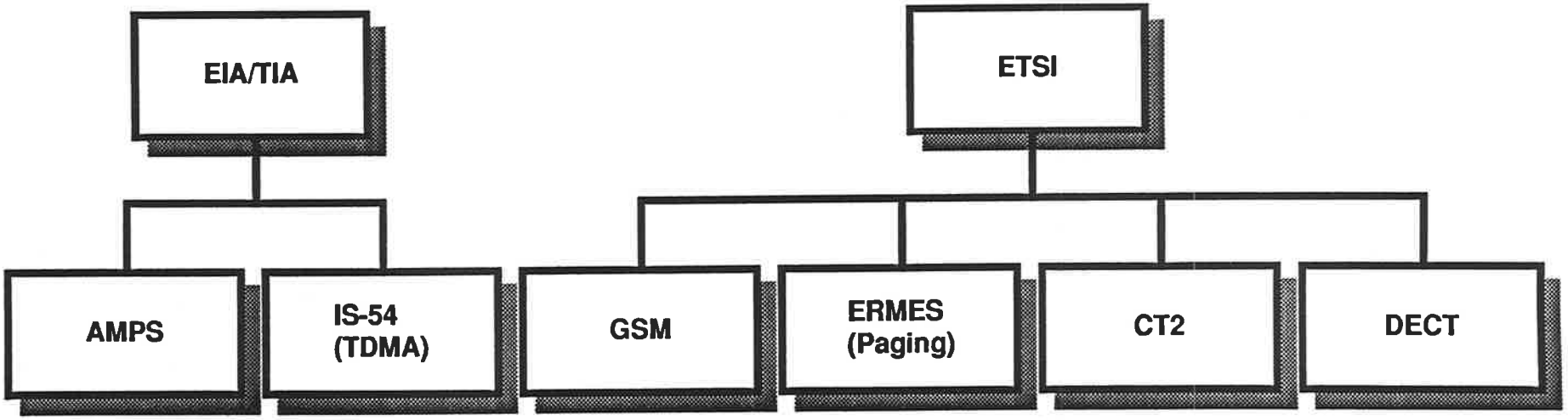
Emerging Wireless Standards



AMPS	Advanced Mobile Phone Service
IS-54	Dual Mode TDMA/AMPS Cellular Phone
GSM	Global System Mobile
ERMES	European Radio Messaging System
CT2	Cordless Telephones, 2nd Generation
DECT	Digital European Cordless Telecommunications

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Channelization	FDMA	FDMA	TDMA/FDMA	TDMA/FDMA	TDMA/FDMA	FDMA	TDMA/FDMA
Channel Spacing (KHz)	100	100	1728	200	30	30	300-400
# of Freq. Chan.	40	20+	11	125	832	832	~170
Total Duplex Channels	40	20+	132	1000	2496	832	1700
Data Service (Max.)	NA	32 kbit/sec	736 kbit/sec	16 kbit/sec	8 kbit/sec	voiceband only	320 kb/sec

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Table 2
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Channel bit rate (kbit/sec)	72	72	1152	270.833	270.833	97.2?	NA	500
Data Service	32 kbps	32 kbps	32-736 kbps	16 kbit/s	8 kbit/s	8 kbit/s	Voiceband only	32 to 320 kbps
Speech coder	ADPCM	ADPCM	ADPCM	RPE-LTP	RPE-LTP	VSELP	NA	ADPCM
Bit rate	32 kBPS	32 kBPS	32 kBPS	13 kbps	6.7 kbps	8 kbps	NA	32 kbps
Frame Time (mSec)	2 mSec	2 mSec	10 mSec	4.6 mSec	4.6 mSec	40 mSec	NA	2 mSec
Modulation	GMSK	GMSK	GMSK	GMSK	GMSK	$\pi/4$ DQPSK	Analog FM	DQPSK
Voice & Data	~no	~some	yes	yes	yes	yes?	~no	yes
Ave xmit power (Watts)	5 mW	5 mW	10 mW	2, 5 MS	2, 5 MS	0.6, 1.2, 3.0	0.6, 1.2, 3.0	400-800mW down
Peak Transmit Power (W)	10 mW	10 mW	250 mW	8, 20 MOB	8, 20 MOB	0.6, 1.2, 3.0	0.6, 1.2, 3.0	100-200 mW uplink
Handoff ?	no	yes	yes	yes	yes	yes	yes	
Cell Radius	41-140 m	40-140 m	40 - 140 m	1 - 5 miles	0.4 - 5 miles	30 miles ?	30 miles ?	2000 feet
Availability	1989	1991	1992	1991?	1993	Late 1991	1983	1994?

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CT2 Technical Overview

- FDMA
  - 40 Channels (864.15 -868.05 MHz)
  - 100 kHz spacing
  - Gaussian FSK ± 14.4 to 25.2 kHz
  - 72 kb/sec
  - 10 mW (12-20dB atten. allowed)
- TDD "Ping-Pong"
  - Single handset antenna
- Dynamic Channel Allocation
  - -94 dBm is a clear channel
  - Random Selection of available Channels

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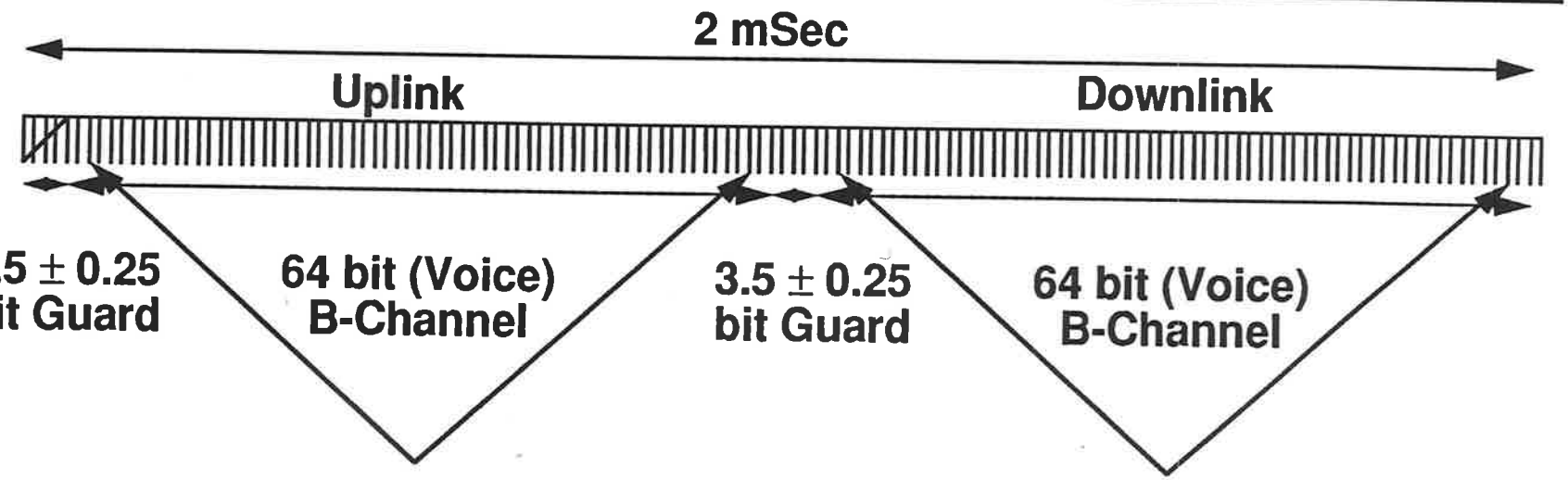
CT2 Multiplex 1 Frame Structure



72 kbps data rate
32 kbps voice rate
1 or 2 kbps signalling channel
(MUX1.2 and MUX1.4 respectively)
B channel is scrambled by fixed pattern

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CT2+ Enhancements to CT2

- 2 MHz dedicated spectrum (930-931 and 940-941 MHz)
- Shared Spectrum over 930-960 MHz
- Accesses 900-959.95 MHz w/ 1200 channels
- Common Signaling Channels
- Handoffs with CCFP
- Encryption supported
- Backward Compatibility with CT2 CAI

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DECT Technical Overview

- TDMA/FDMA
  - 12 Time Slots x 10 Frequencies = 120 Servers
  - 1.728 MHz Channel Spacing
- Gaussian FSK ± 259 kHz to 317 kHz
  - 1,152 kb/sec
  - 80 mW to 250 mW peak power
- Asymmetric Timeslot Allocation (Data)
- Frequency Agile Between Timeslots?
- Dynamic Channel Allocation

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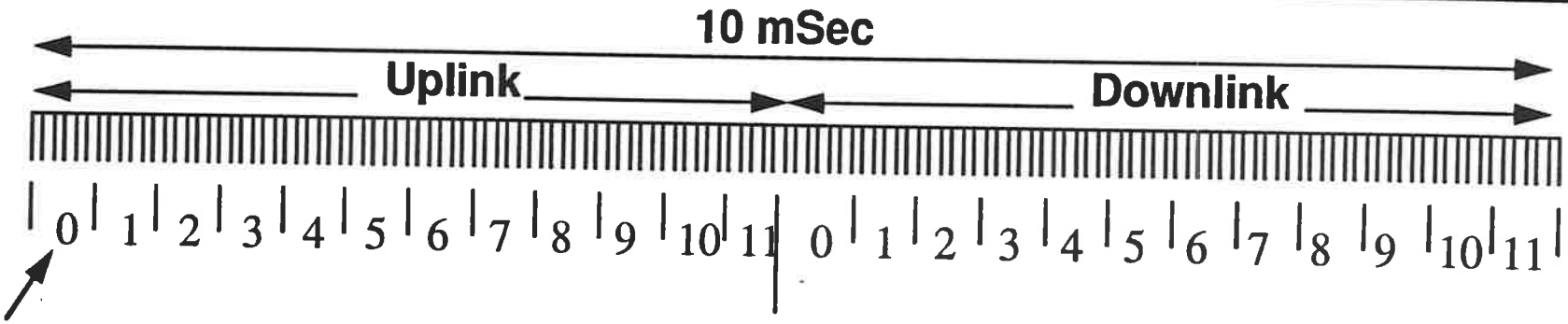
DECT Frame Structure



full Slots

480 bits

420 used

11520 bits

- 12 time slots
- 1152 kbps
- Each Full Time Slot gives 32 kbps ADPCM
- Half-slots gives 16 kbps

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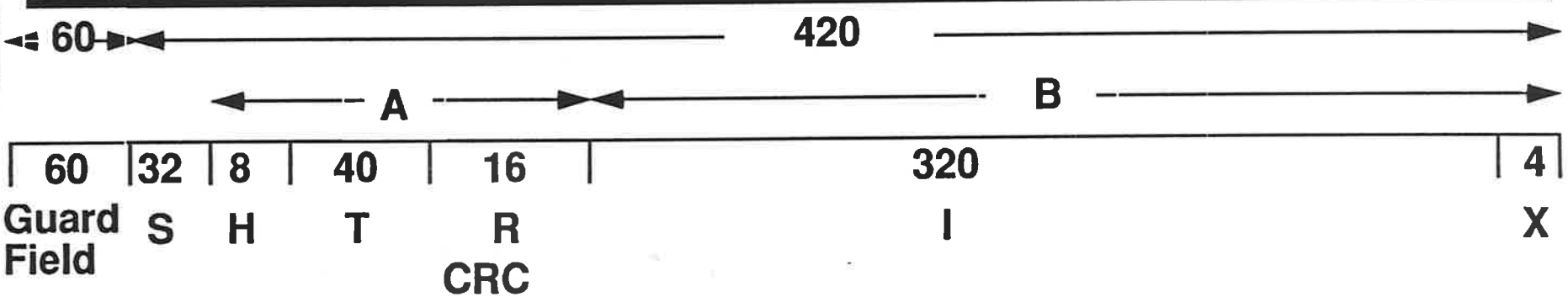
DECT MAC (U1 Mapping)



- 3 Other mappings supported including no voice signalling/paging
- Frequency Adjustment & Time Slip signalling in the H channel.
- Half Slots also supported for variable rate vocoders.

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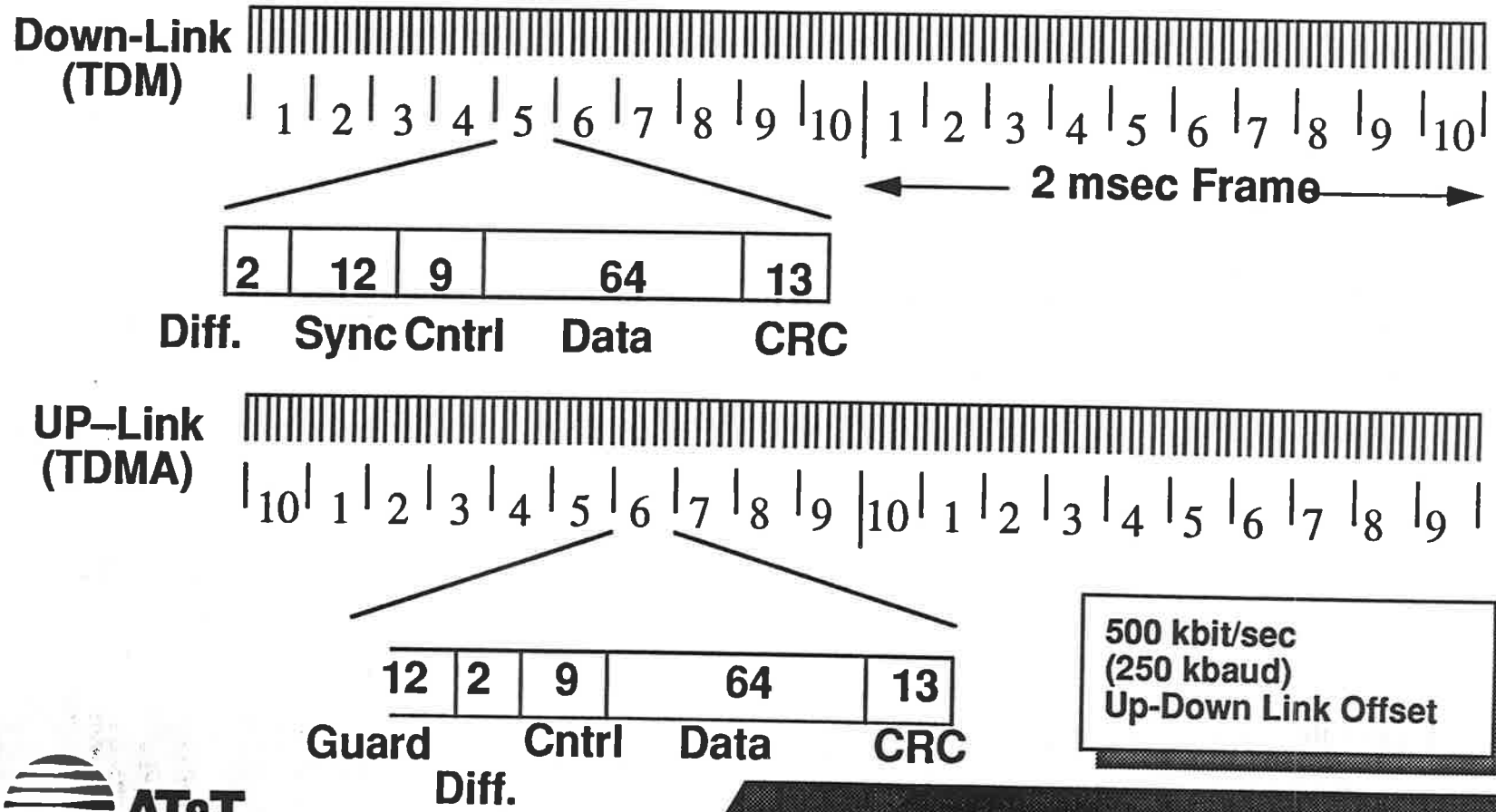
UDPCS Technical Overview

- TDMA/FDMA
  - 10 Time Slots x ? Frequencies = 1700 Servers?
  - 300-400 kHz Channel Spacing Proposed
- DQPSK — Nyquist Filtered
  - 450 kbit/sec (each direction)
  - 400-800 mW downlink, 100-200 mW uplink
- Frequency Division Duplexing
  - Staggered Up & Downlink
- Self-Structuring Frequency Assignment Proposed

UDPCS Frame Structure



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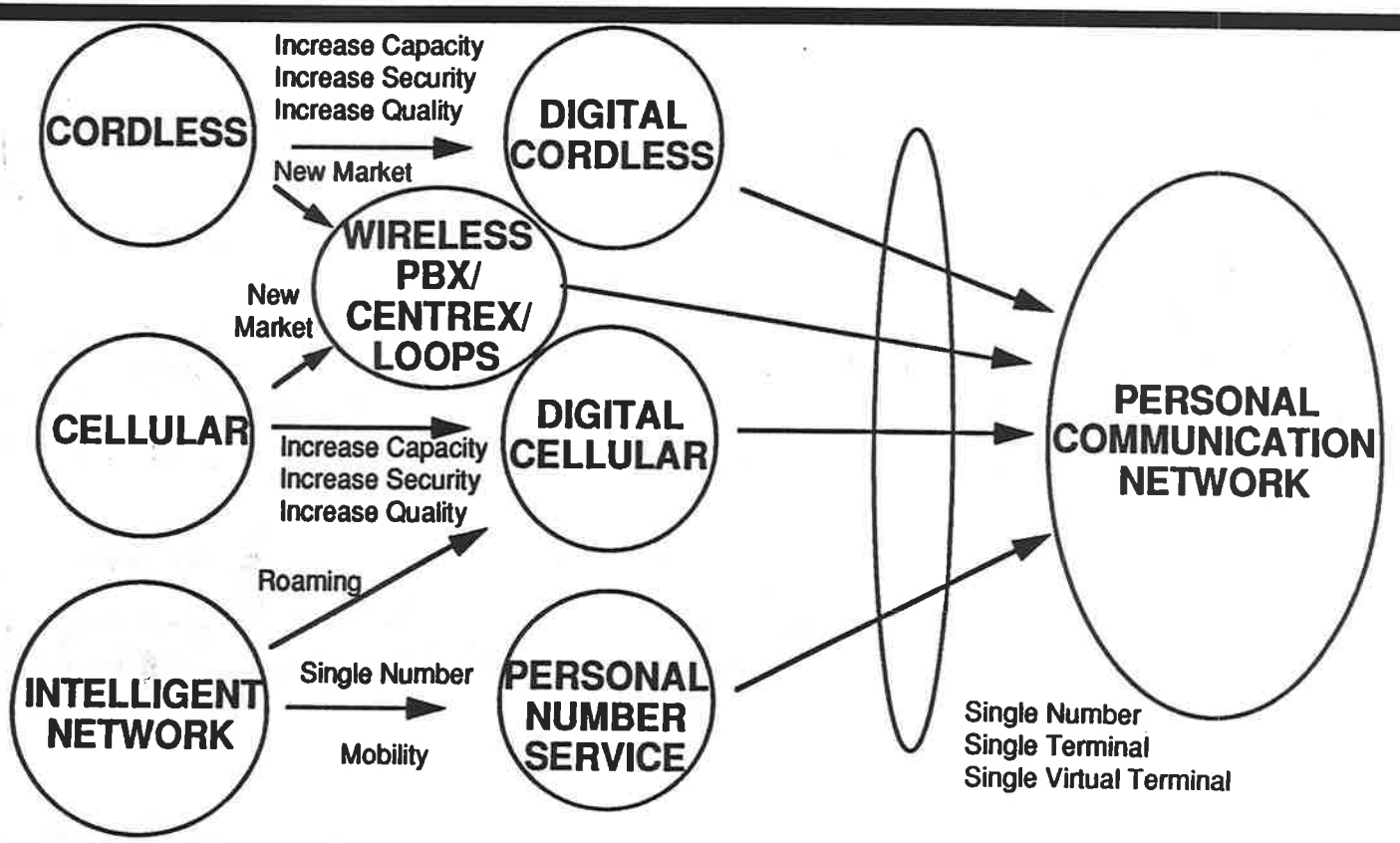
Possible PCS Evolution



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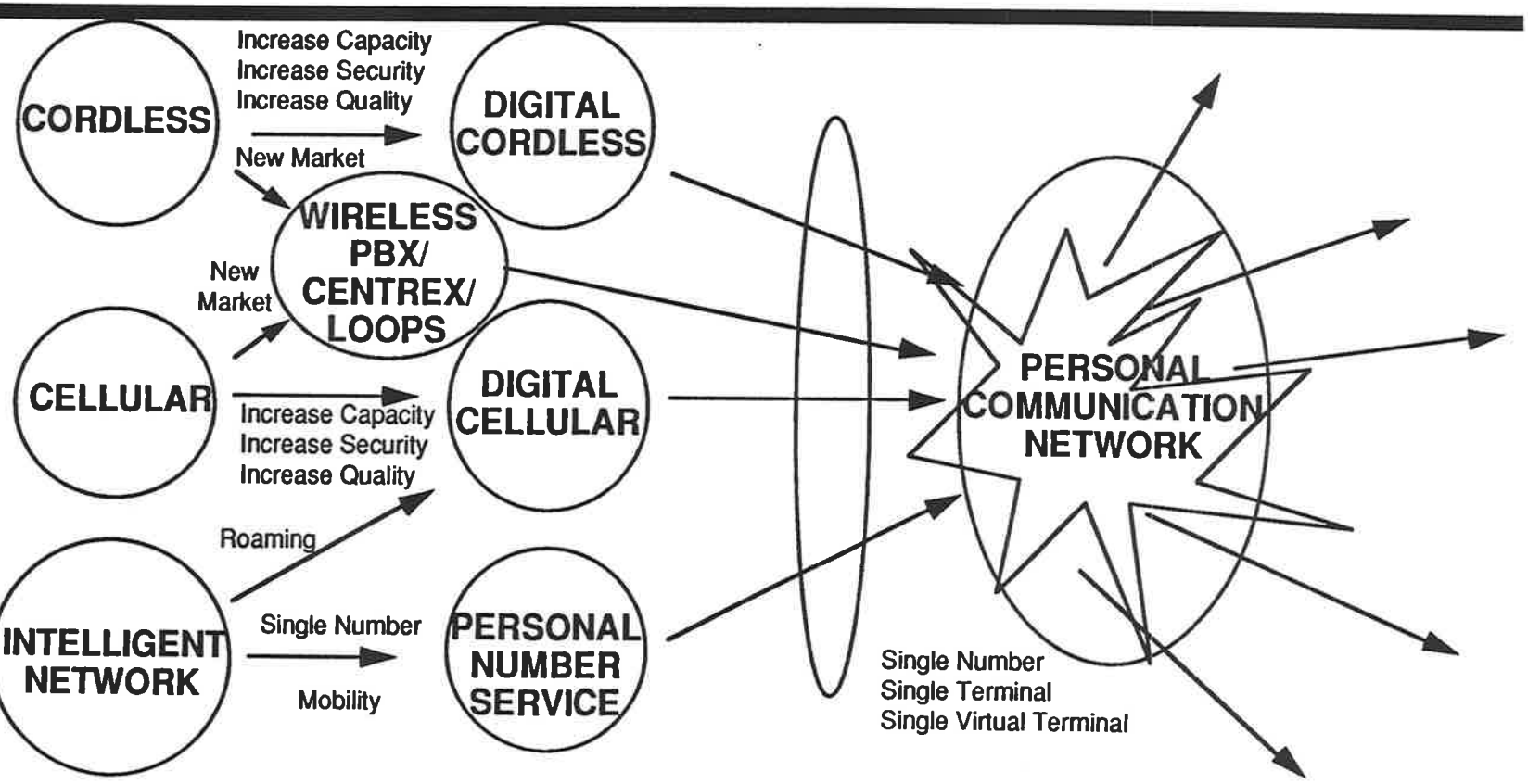

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Forces Opposing Standardization

- Different Environments
  - Indoor/Outdoor
  - Public/Private
  - Intra-Network/Extra-Network
- Different Applications
  - Data/Voice
  - High Speed Data/Low Speed Data
- Different Spectrum Allocations
  - US/Europe/Global
  - Auctions?
- Proprietary Business Interests

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