Cross Standard System for Future Public Safety and Emergency Communications.

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Abstract

Public safety community shows an increased interest in standardized communication and information system that could support reliable technology transparent multimedia communication during multinational emergency operations.

The introduction of public safety communication system that will be able to use all available means of communications, including rapidly deployable networks, to cope with large scale disasters or/and to implement preventive measures is very important today.

The article provides a survey of existing public safety communications systems; discusses their evolution, current status of research activities and presents the idea of cross standard communication system (CSS). It provides an overview of the key research problems in CSS development.

I. INTRODUCTION

The existing public safety communication systems are based on several of different standards and are often unable to talk with each other. The problem of interoperability between different emergency and public protection communication systems exist at national and international level. This problem is one of the most critical elements of public safety operations today. The budgetary constraints and technical possibilities of existing public communication system to provide support or back up for public safety communication suggest us to take into consideration multiple standards -based system approach. At the same time it is considered very unlikely that we can expect an introduction of a new globally harmonized multimedia private public safety communication system in the future due to the very large investments to be required. The Private Mobile Radio (PMR) market is too small to justify large industrial investments in R&D and PMR networks installation is usually funded by governmental budgets.

The Cross Standard System (CSS) could provide a solution to this problem. It could use efficiently existing wireless systems and rapidly deployable ad hoc communication networks.

The CSS could be quickly optimized according to different operational scenarios and is more efficient, reliable and survivable than multiple systems interpretable at IP level.

The progress in heterogeneous wireless multi-standard systems design, new developments of software defined radio terminals, introduction of rapidly deployable broadband networks let us presume that CSS could the next logical step in the evolution of public safety communication technology.

This article presents a survey of existing public safety communication systems including infrastructure –based and rapidly deployable systems and discuss their evolution. It provides a generic idea about CSS and highlights the key challenges in its development. It informs about on going research and standardization activities

The goal of the paper is to make wireless research community more familiar with the key research problems in future public safety communication systems development and to encourage more active participation in public safety systems development and standardization processes.

II. SURVEY OF WIRELSS PUBLIC SAFETY NETWORKS

Infrastructure –based public safety communication systems

The APCO Project 25 in US, TETRA and TERAPOL in Europe are the first generation PMR narrow band digital communications architectures for public safety and internal

security tactical communications and information interchange.

These technologies satisfy a broad range of specialized wireless communications requirements particularly applicable to public safety including:

- promoting the notion of tactical wireless communications networks including digital voice and digital multimedia data
- establishing a common tactical wireless communication networks, common network backbone infrastructure, and separate command and control multi-agency scenarios permitting the maintenance of agency autonomy while promoting cooperative system usage
- supporting both infrastructure and non-infrastructure based communication usage's
- provision of networked electronic cryptographic key management

PMR systems support a number of teleservices such as point to point call, group call, broadcast call; bearer services such as enciphered digital data, packet switched confirmed/unconfirmed data delivery, circuit switched reliable/unreliable services and supplementary services such as priority call, call interrupt, talking party identification and others.

APCO Project 25

APCO's [1] Project 25 [2] is a digital trunking standard for the US public safety market and is based on FDMA, 12,5 kHz technology. For APCO 25 - phase 2, it is decided to introduce TDMA-technology, as used in Tetra, in addition to the narrow band FDMA 6¼ kHz version. The APCO 25 uses cross channel rate 9.6 kb/s. It provides typical cell radius 7.6 km (handheld suburban) 35 km (mobile rural) for interference limited system.

TETRA

TETRA [3] is ETSI [4] standard for PMR that used by considerable number public safety agencies across the globe. TETRA uses time division multiple access (TDMA), RF carrier spacing 25 KHz, cross channel rate 36.6 kb/s. The typical TETRA cell radius is 3.8- 17.5 km for interference limited systems.

Some countries achieved a countrywide coverage of TETRA network and have a dedicated national operator organization [5] to run their operation.

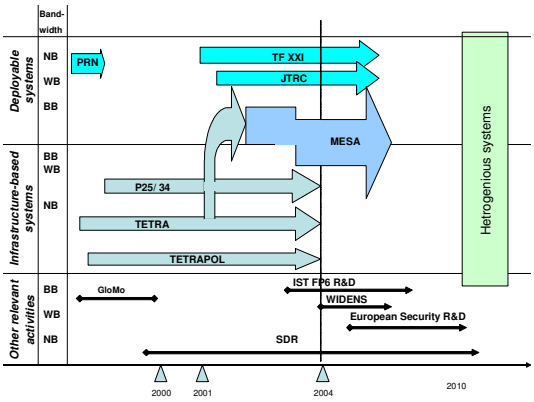

Fig.1. Evolution of public safety communication systems

TETRAPOL

Tetrapol is the name for PMR technology of the French company Matra. France chose this technology for their Police. The Police networks are known as Rubis and Acropol. Also there are Tetrapol networks in Spain, the Czech Republic and Switzerland. The users of these systems have joined together in the Tetrapol Forum [6]. The Tetrapol technology is similar to APCO P 25 it uses FDMA with RF carrier spacing 12.5 kHz and GMSK modulation.

Public wireless networks

There are several ongoing discussions on possibility to use public networks for emergency communications. The budgetary considerations are used to advocate this idea; however, many public safety agencies are reluctant to consider this option seriously for the moment.

The white paper provided by Ericsson [7] describes how public mobile networks, specifically GSM and its evolution into 3G access, can be used to meet the communication demands of different agencies in the public safety sector. According to white paper such networks, using the latest technologies will become a future-proof, technically and economically viable alternative to dedicated networks. This white paper is intended to inform government bodies, various agencies, regulators and network operators about these possibilities and to outline Ericsson's intentions.

An Ericsson Response Unit consists of telecommunications equipment and the people to implement and operate it. Initially standard cellular networks, with satellite or microwave for link to public network will be used.

Communication infrastructure with improved survivability

An important issue is a survivability of network infrastructure that supports emergency communications. This issue is getting increased attention of research community. Several different approaches could be used [8, 9] to increase the reliability and survivability. The use of SONET rings to interconnect base stations /MSCs , introduction of multifunctional/ multimode phones, establishing an overlay network and higher density BS architectures had been proposed. Several survivable heterogeneous architectures with priority based QoS schemes had been studied by simulation [10]. Interesting results of network behaviors simulation studies at different stages of disaster life-cycle model are presented in [11].

Ad hoc network and rapidly deployable systems

The development and exploitation of ad hoc wireless communication had been started by military.

DARPA probably was among the first who had initiated Packet Radio Network (PRN) program [12] in 1972. Although the initial PRN Protocols used a centralized control station the core PRN concept had quickly evolved into distributed system with multi-hop store forwarding techniques.

In 1983 DARPA had initiated the Survivable Radio Networks (SURAN) program [13] that had enhanced scalability feature, and could use small, low cost, low power radio with more sophisticated packet radio protocols.

The current research and development activities in the area on the military side include:

Tactical Internet (TI) – the US Army's Task Force XXI (TF XXI) program (1997) [14] is probable the largest implementation of mobile wireless network (MANET) and consist of thousands nodes that include vehicular and man-packed radios. It is running modified commercial Internet protocols and uses direct-sequence-spread-spectrum, time-division multiple access radio capable of transmitting data at tens kilobits per second.

In 1994 DARPA has initiated Global Mobile (GloMo) Information Program [15] which was concluded. It aimed to provide office-environment, Ethernet-type multimedia (voice, video, images, etc.) connectivity any time anywhere in handled devices, not just in devices mounted on platforms moving in the air or over water or land.

The future generation of adaptive, multi-band, multimode radios - the Joint Tactical Radio System (JTRC) [16] will offer improved flexibility over half-duplex, single-channel radios at higher layers of the system because of the ability transmit and received on different bands and using different waveforms. The next important step in JTRC development will be the integration of broadband transmission capabilities in the systems.

Several research projects in the area of mobile wireless networks had been lunched by academia. The Bay Area Research Wireless Access Network: Toward Wireless Overlay Internetworking Architecture [17] had been carried out University of California at Berkeley in cooperation with industry. The heterogeneous ad hoc network architecture, protocols had been studies and implemented in prototype.

Ad hoc wireless network for communication between vehicles had been proposed and studied by several organizations in US, Europe and Japan [18].

The development of ad hoc rapidly deployable broadband network demonstrator and system concept for public safety is the main goal of the European IST FP5 research project WIDENS [29]. The WIDENS project will provide contribution for MESA standardization process.

The design of Wireless Deployable Network System for public safety is a challenging task. The number of wireless ad hoc network features such as:

- dynamic topologies
- bandwidth-and energy constrained
- asymmetric links with variable capacity
- conflicting issues related to QoS, mobility and security

making the design task more difficult.

A trade off between centralized and distributed algorithms has to be established and different emergency scenarios and public safety user requirements have to be taken into account.

Evolution of public safety communication systems. Standardization efforts.

The Tetrapol forum had tried unsuccessfully to get it recognised as an official ETSI standard. However, there has been an agreement to find solutions for interworking between Tetra and Tetrapol.

The standardisation activities of APCO project 25 supported by TIA [19] TR-8 Engineering

Committee, Mobile and Personal Private Radio Standards. The Engineering Committee and its Subcommittees develop and maintain standards for private radio communications systems and equipment for both voice and data applications. TR-8 addresses all technical matters for systems and services, including definitions, interoperability, compatibility and compliance requirements.

There was signed a partnership project between APCO and ETSI in 2000, for APCO Project 34 (wide band mobile data communication – part of APCO P25) where the ETSI developments for wide band data communication DAWS project, supposed to be used. DAWS was indented to produce specification for high speed broadband mobile multi-media possible.
The project name was "PSPP – Public Safety Partnership Project". In the year 2001 the PSPP project was transformed into TIA-ETSI transatlantic project MESA [20].

In the area of wireless ad hoc network standardization the MANET chartered Working Group was established in 1997 within Internet Engineering Task Force (IETF).The MANET [21] activities are focused on studying routing specification with the goal of supporting network scaling up to hundreds of routers. Work relies on the existing IETF standards such as mobile-IP and IP addressing. The largest number of valuable contributions and studies for MANET were supported and /or co-ordinated by NIST [22].

Beside MESA project the European standardisation activities of several ETSI bodies such as BRAN/HiperLAN2 and 3GPP projects had considered ad hoc network functionality. However there is a strong need for standardization for the ad hoc network layer at this moment.

The evolution of public safety communication systems and related projects and activities is presented on the Fig. 1.

III. CROSS STANDARD SYSTEM CONCEPT

The development of wireless communications systems is more driven today by applications rather than by advances in new technology and wireless communication becoming more technology transparent.

Future communication systems will be able to support several air interfaces and will provide multimedia services in heterogeneous network environment.

It is reasonable to consider the future public safety heterogeneous communication systems as a two component structure that consists of a multi-standard communication system and set of applications that could use normalized public safety data and will use the advantages of new types of user interface.

The two-element structure could be jointly optimized according to different emergency scenarios, type of sub network included and operational considerations Fig. 2.

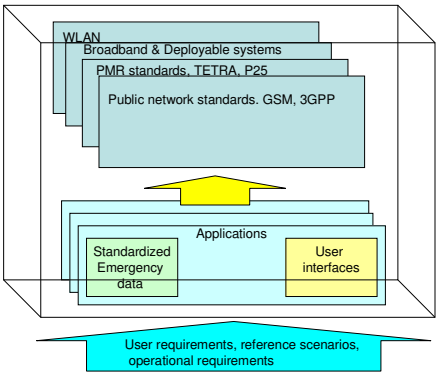

Fig. 2. Generic structure of CSS

The CSS could have a centralized or distributed network control and use several sets of adaptive network control protocols.

The CSS will provide an opportunity to distribute different type of services and application among different (parallel) sub systems according to the service prioritization, bandwidth requirements and topological distribution of terminals and wireless sensors.

This concept will solve the interoperability problem in a much more efficient way than the multiple independent systems interoperable at IP level.

The survivability and reliability will be dramatically improved since the failure of one sub system could automatically handover the communications to another sub system.

CSS architecture and topology could be optimized in fly adaptively according to variation in emergency scenarios. In this case, the multimedia emergency applications will be able to adapt to the changes in scenario and network management will incorporate the situation awareness in its control algorithms.

An integrated "applications-network" scenario aware approach has to be established to allow close cooperation between adaptive

network management and adaptive applications to ensure the delivery of the most critical information.

The standardized formats of emergency data are the essential part of future multimedia emergency wireless applications. The new multimedia public safety applications will take an advantage of new types of user interfaces that will include head-up displays. The introduction of sensor networks with broadband video transmission capabilities, wearable networks, possibility to follow the location of emergency workers and remote monitoring of peoples bio-medical parameters will provided public safety applications with new capabilities and will save life of many people.

The public safety CSS will be based on architecture that will integrate an infrastructure – based network and rapidly deployable ad-hoc network that will be used in the areas with destroyed communication infrastructure or in the remote regions Fig. 3.

The CSS architecture has to provide high level of system adaptivity, survivability (self-healing system) and scalability. It should be able to use interoperable relaying mobile platforms (RMP) and repeaters that could support broadband communication, PMR and public network air interfaces at the same time.

The development of CSS is very complex task it will require multidisciplinary efforts of industry, regulators and authorities Fig. 4.

The singe industrial group or one nation effort will be not sufficient to carry it.

There are several ongoing activities and developments in research, standardization and in international public safety policymaking that will create multidisciplinary platform for public safety CSS development.

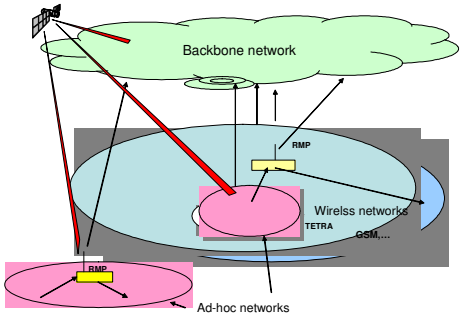

Fig.3. The elements of public safety CSS

Industrial programs and R&D activities

The heterogeneous network [23] and reconfigurability is the hot topic of the wireless research today. The key concepts of reconfigurable heterogeneous systems and architectures could be applied efficiently in public safety systems. There are several IST FP6 [24] European projects [25, 26] that are currently focused on research in these areas.

The Software Defined Radio (SDR) will be an essential part of CSS. Recently the SDR forum [27] provided an indication of its interest in public safety. The first SDR public safety workshop was held in Mainz [28] in April 2004.

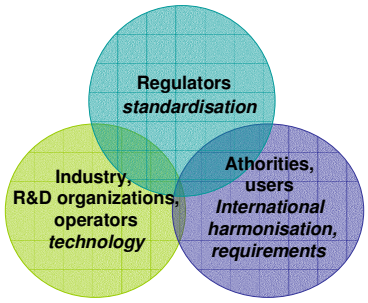

Fig.4. Main contributors of CSS development process.

Several European projects dealing with different research issues relevant for future public safety communications were established.

The WIDENS project [29] is developing ad hoc broad band rapidly deployable wireless network for public safety. The public safety user localization techniques are in the focus of IST FP6 projects SCORE and EUROPCOM. The first project is studying the GPS technique and the second is focused on Ultra Wideband (UWB) indoor radio localization.

The IST FP6 OASIS integrated project aims to define a generic crisis management system to support response and rescue operations in case of large scale disasters and includes a communications framework.

The integrated approach in information and communication system crisis management is promoted by ITCM initiative [30].

The preparatory action on the enhancement of the European industrial potential in the field of security research [31] includes several projects dealing with aspects of information and communication systems interoperability.

Standardization

The MESA -7th project meeting introduced the system of the system concept approach as its key strategic objective for future public safety communication systems specification development.

The standardization of emergency information system components is considered by C4I DTF which is a Domain Task Force of the Object Management Group (OMG) [32] that operates under the Domain Technical Committee and is focused on systems that support crisis response, Search and Rescue (SAR) and military operations.

The ETSI's OCG EMTEL [33] is focused on cross standard issues of public safety communications.

The hybrid communication system was included in the study item list of the recently established European forum for public safety communication officials (EPPCO). The EPPCO forum will facilitate the international harmonization and road map developments which are very important for establishing future European integrated interoperable public safety communication system.

CONCLUSION

The public safety CSS could solve the major problem of public safety communications – the interoperability problem.

It could improve the operational efficiency of emergency and crisis management operations by:
- introduction of new broadband services
- higher level of survivability and reliability
- rapid deployment features
- rapid adaptation to variations in scenarios

This could be achieved with lower level of investment in equipment and more efficient use of spectrum.

The CSS could be considered as a next logical step in the evolution of public safety communication systems that will merge together different communication technologies and will use the advantages of SDR and heterogeneous network architecture.

Meanwhile the CSS development is a challenging task and requires multidisciplinary international harmonization efforts that will involve key players from research, standardization and public safety communities.

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