1. INTRODUCTION

MOTIVE, TOPIC AND BACKGROUND: AN INTRODUCTION

Integrated Safety Systems and Interoperable Systems of Systems catering to the need of Life and Society is an important emerging need in this Information Age. Governments across the field, both local administration and Central Administration are developing standards, systems and procedures towards this important mission. Communications is an Important Aspect in Systems of Systems Realization and since Internet Protocols(IP) have emerged as an Common Universal Communications mechanism, system designers and engineers tend to use IP i.e. TCP – IP as a common backbone for communications. In this premise Emerging Public Safety Broadband Networks, Machine to Machine (M2M) all tend to utilize the ***All – IP Flat Network*** as the Communication Language, while there could be different medias like Ethernet, Cellular (2G, 3G, and LTE), Specific Wireless Bands i.e. in WiMAX, Airport Networks etc.

Safety Management can be defined as a businesslike approach to safety. It is a systematic, explicit and comprehensive process for managing safety risks. As with all management systems, a safety management system provides for goal setting, planning, and measuring performance. A safety management system is woven into the fabric of an organization. Globally governments have begun to adopt a national broadband plan and also provide a dedicated spectrum for Public Safety utilizing the Evolved Packet Core Long term Evolution cellular technology. Safety Management deals with both the prevention of accidents and as well as managing emergencies. The suitability of the LTE networks and the architectures for emergency response has been detailed out by the Dept. of Homeland Security [1]. The systems thinking paradigm creates a human centred approach in the systems design and the overall system safety is then a function of interactions, interfaces and risk reduction by proactive monitoring and probabilistic failure models.

1. RESEARCH MOTIVE

The Technology maturity has always been leading the world to an automated world with rapid Industrialization and advancement in Electronics / Semi Conductors / Nanotechnology are tending to create a world that is more productive, more secure and safer world. With the rapid advancement in the communication systems and internet and with the adaptation of Internet of things on the IPv6 the technology is matured to provide a connected and co-operative world. This has led to the revolutions in energy management like the SMART Grid Initiatives, Cloud Computing, Infrastructure as a Service and the like.

Technology into ensuring safety of systems and infrastructure has been developed continuously leading to state of the art of Fire & Gas Systems, Chemical –Biological – Radioactive – Nuclear Threat Management Systems, Systemic Management of Man Made Disasters and Natural Disasters. Layers of Protection have been established and International Electro Technical Commission (IEC) has developed Safety standards in various forms from System Safety to Ecology Safety with underlying IEC 61508 safety integrity framework. As another Layer of Protection, we have built the First Responders & Incident Management teams which handle situations like fire accidents, threats & disasters and the like. As in Military, this team usually called Homeland Security group in the United States deployed their Land Mobile Radios, which are usually called the Walkie-Talkies to effectively communicate with each other. As the Communication Systems Technology has been developing over the last decade and effective focus in the industrial community has shifted to Data Communications, the need to upgrade the communications infrastructure for this Public Safety Community has been felt across the globe from North America, Europe, India, and China in standardizing a spectrum for Public Safety in the new broadband era, and providing them adequate applications helping them to Manage the Threat (or) Disaster effectively and with acceptable speeds.

When we just think of broadband era, we immensely think about the high speed connectivity that has been created between systems and people using rich media services like video streaming, data on the cloud and the like. Advancement in Broadband technologies have been effectively put into use only because of continuous evolution and enhancement of the Internet and its Internet Communications Technology i.e. the IP Protocols.

Hence it becomes inherently intuitive to identify the IP Communication Mechanisms and desired Quality of Service Parameters for different applications that would be communicating in a Cooperative Safety System.

Coming with a Background in Communications Engineering, and working on designing the latest Life Safety Systems, I wanted to pursue a detailed research in equipping the Public Safety Systems, with right kind of information networks that shall be required to perform & manage the Safety Missions.

2. PROBLEM STATEMENT

In case of accidents and disasters the public safety teams haven't been able to successfully able to manage the threat or the condition and also do not have pre-conditions about the incident. If one looks back at Carlton Fire that happened in Bangalore in 2010, until 3 days the First Responders had not been able to identify the cause of the fire. Also it took time for the fire fighters to reach the place and then devise the strategies to save people. But by this time three people jumped of the windows losing their lives. Similarly an operations plant, power plant or an oil rig is a high probable place of disasters and incidents. The Occupational Safety & Health Association in the United States runs the mandatory compliance practices, but still providing a Proactive Safety Systems has been a need long since.

From the literatures in this area on Evolution of Public Safety Applications, System of Systems is considered to be a Medium -to- High Feasible Solution from California State as seen in Table 1.

The CAPSCOM defines 7 major Goals in its Endeavour and Goal 4 is to Establish System of Systems Architecture and Infrastructure, with the following objectives

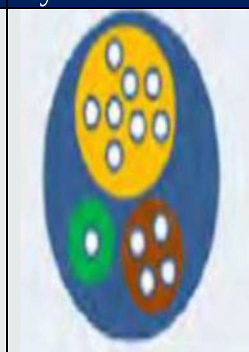
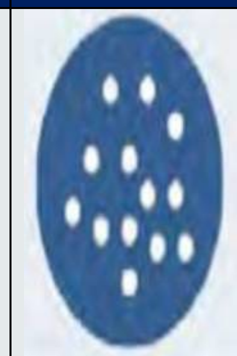
a) To Develop Common Communication Backbone utilizing the National Public Safety Broadband Networks

b) Interoperable Systems Design amongst various Public Safety Agencies.

The Public Safety Architecture Framework (PSAF) of the SAFECOM defines various Operational Views (OV) and System Views (SV) for the Architecture Framework. System Views SV -2 depicts the Communication Architectures in terms of Nodes and Network Elements. Beyond this the Communication Design in not dealt to a greater extent.

The SAFECOM program's Statement of Requirements details the various requirements for a Public Safety Communications from different actor's perspectives and also gives a qualitative Functional Requirements for the Communication Systems. Many network providers and System Integrators are defining how they would like to use the Emerging Broadband Networks for Public Safety Needs. The mission is here to make the different applications communicate with each other effectively. Various applications are shown in Figure 1.

TABLE 1 CALIFORNIA STATE PUBLIC SAFETY ALTERNATIVES

Alternative	Stovepipe Systems	Single System	System of Systems	National Broadband Soln.
Description				
Benefits	Low	High	Medium – High	High
10 yr cost	$$	$$$	$$	$$
Flexibility	Low	Low	Medium – High	Low

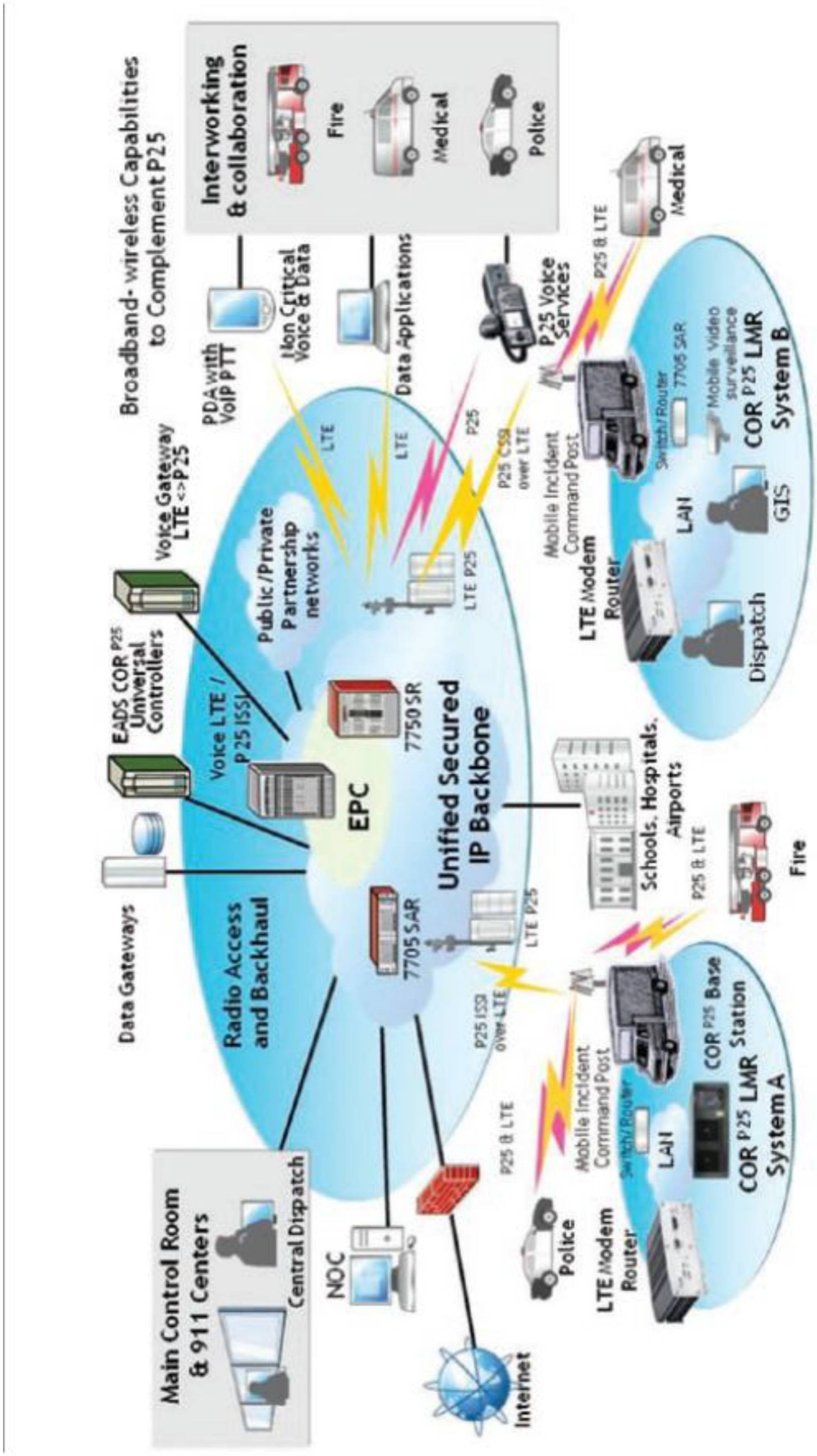


FIGURE 1 NEXT GEN PUBLIC SAFETY APPLICATION

The LTE Broadband networks could eventually support the following

- **Streaming video / sensor information (surveillance, remote monitoring)**
- Digital Imaging
- Automatic vehicle location
- Computer Aided dispatching
- Web access
- e-mail
- **Remote database access**
- **Report management system access**
- **Telemetry & remote diagnostics**
- Mapping & GIS
- Text Messaging
- VoIP including interoperability with legacy and new LMR infrastructure.

The elements highlighted in bold indicate a topic of research interest as there are lots of proprietary information systems with different information structures and protocols. **A clear need to develop Cooperative Safety Systems is felt and be realized in Systems of Systems approach.** In premise of the above requirements, it becomes critical to design effective Communication System as the critical Backbone. Being a Safety Function, by itself, it becomes critical to evaluate the Functional Safety aspects of this type of Systems as well.

3. RESEARCH OBJECTIVES

The objective of this research journey is to Design the Communication Systems for Cooperative Life Safety Systems, in a ***next generation All – IP Flat Network*** running over different physical media like Public Safety Networks, General Broadband Backbones and the like.

A Communication System Design, encompasses the following steps

a) Source Modelling & Information Modelling
b) Channel Modelling
c) Functionality Needs and Methods
d) Validation

The research was targeted towards Communication System Design for Cooperative Life Safety Systems **using public safety LTE networks**, the research objectives were stated as

TABLE 2 RESEARCH OBJECTIVES

Source Modelling & Information Modelling	Identify different information to be communicated
Channel Modelling	Since public safety LTE is the channel, and hence identify protocols to communicate in All-IP flat networks
Functionality Needs and Methods	Develop methods for intended communication and since the design is to cater the needs for Safety systems, identify functional safety needs.
Validation	Perform a validation of the communication system with different usage scenarios.

4. RESEARCH METHODOLOGY

FRAMEWORK

The Communication Systems Design of this Cooperative Safety Systems was governed by four major elements

- Accident Analysis and functional safety
- Interpretations of cognitive elements related to safety
- Information Model and Actors identification
- Communication Definition & suitability analysis.

With regard to this the research was planned to develop these four work items.

e) Review of functional Safety Models for Safety Management Systems.
f) Functional & Cognitive Safety Aspects for Disaster Preparedness & Management.
g) Safety Information Modelling in the IoE context
h) Safety System Design – Architecture, Models & Communications.

SCOPE

The Scope of this entire research project was limited to Modelling Hazards related to Fire, Gas & Chemical. The derived models shall be capable of handling the Generalization to other Safety Related Instruments. During the course of the research and review of accidents, ***chemical tank storage** was identified as the element with higher probability of risk and it was used as the **case** for this research.*

5. LITERATURE SURVEY

Gabbar & Suzuki [2] present a systemic design of Enterprise Safety Management System, in line with the CAPE OPEN Standards for Process Modelling and Simulation. This Japanese research helps in understanding the Modelling methodologies that can be adapted to the case of next generation public Safety System.

Knight & Graydon [3] represent, the process involved in designing Safety Related Systems, in line with IEC 61508 Safety Related Programmable Electronic Systems [SR-PES]. IEC 61508 holds the basis for Functional Safety in Electrical & Electronic Programmable Electronic Systems. This Paper presents the essence of Communication in Engineering for Safety Systems. This paper brings out the importance of objective and verifiable requirements, and developing those requirements.

Ribeiro et al [4] have studied the effect of TCP in wireless networks and measured the Propagation Delay in different configurations. They conclude with their experiments that, on an average Wi-Fi network could perform better to provide near real time data for mission networks.

OASIS (**Organization for the Advancement of Structured Information Standards**) has developed the XML based exchange format, including the Common Alerting Protocol discussed in EDXL V1.01. This standard has been widely adapted for alarm communications for emergency management. On the other end NIEM- National information exchange model, USA, has developed, emergency management domain of information model used by homeland security [5].

Desirable Properties of Public Safety Network [6] elucidate the various needs and requirements of this new generation network. They also put forth the Idea of Public Safety Interoperability Panel (PSIP), as similar to the Smart Grid Interoperability Panel SGIP. They put focus on various trust areas that should be technically challenged in this Public Safety Network. A detailed summary is provided here.

1. Flexible Communication System Architecture : Continuously Evolving
2. Using Internet Protocols
3. Backward Compatible – Software Defined Radio vs. Multiple Radio

4. Mesh & Mobile Ado Networks
5. Robustness & Recovery
6. Security & Authentication
7. Standard Application Development – Interoperable Common Models similar to Smart Grid Initiative
8. Ruggedization
9. Sensor & Location Systems
10. High Density Radio Operations
11. Next Generation 911 – IP Networks

The subsequent chapters (chapter I … IV) detail out the research on elements marked for analysis, hypothesis and design. A brief flow chart is given below.

TABLE 3 RESEARCH OUTLINE

Chapter	Title	Subject
I.	Research Hypothesis Review of Accident Models and Communication System Needs	Methodology Models Needs Hypothesis
II.	Use case and Actors : Elemental Functional & Cognitive Safety in Disaster Preparedness & Management	SoS View & Safety Grid Functional, Cognitive and Situational Safety Case selection : Chemical Storage Tank OSHA Emergency Response Criteria NIEM Emergency Management Model Discussion & Needs Prioritization
III.	Information Model : Safety Information Model in Internet of Everything – Process , People and Things	3GPP Public Safety LTE network work items Internet of Everything & Smart Objects Safety Information Modeling : Disaster Prevention Safety Information Modeling : Disaster Containment Discussion : People, Process & Things Segregation Sample Visualization
IV.	Architecture , Model & Transport : CoAP communications in Thing Architectural framework	System Context Function Blocks and Communication Profile Service API & OR3C interface definition Case Analysis : Storage Tank Safety

6. REFERENCES

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