Risk and Scenario based Communication System-of-Systems Design

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***Abstract*— Designing a communication system that can provide persistent communication in a variety of scenarios cannot be achieved through the implementation of a single technology. This paper discusses the process used to design a system-of-systems persistent communication system that can address various risks and address various scenarios. A model that provides scalable functionality across various scenarios is presented. The result provides enhanced functionality under normal conditions and provides for emergency communication under high stress situations.**

Keywords—risk, scenario, communications, systems design

I. Introduction

Scenario planning is a strategic management tool that encourages managers to envision plausible future states [3]. In this paper different scenarios that could influence communications systems are defined. The influence of the scenarios of the persistence of communications systems are then used to design a persistent communication system that makes provision for graceful degradation. Various technologies are then identified that can meet the system requirements although the functionality may be downgraded depending on the active scenario.

This approach ensures that provision of functionality during the ideal scenario is not downgraded to simultaneously make provision for less-than-ideal situations.

Comprehensive communication systems that provide broadband capabilities relies on external elements, such as power provision or fixed network infrastructure, to provide a service. These external elements may not be available under certain circumstances e.g., in the case of a major power failure. Identifying these external elements and the failure modes thereof is essential for the design of a persistent communications system.

In this paper a set of scenarios is defined, system elements that could fail are identified and the various options and fallback modes are define in order to design a persistent communication system.

II. System Requirements

The overall system requirement was to provide persistent communication for various geographically dispersed facilities as well as for a convoy of vehicles. The fundamental requirement is for voice communications between all the facilities, the convoy, entities at the facilities and entities roaming outside the facilities or the convoy. When available services such as online meetings, location sharing, and video streaming must be accommodated.

III. Scenarios

Four scenarios were defined. Green-Pastures, Fire, Drought, and Apocalypse. The scenarios are described in terms of the long-term availability of electricity, the availability or degradation of key reliant elements, and the probability of the scenario. Although certain risks are combined within scenarios it is based on plausibility of the risks realizing at the same time.

The Scenarios provides a means to easily communicate why the various elements of the total system design is necessary in order to provide persistent communications.

A. Green-Pastures

In the Green-Pasture Scenario a stable electricity supply is available, and the communication system makes no provision for power failures. In this scenario it is assumed that an external IP-backbone is available between the facilities. It is further assumed that mobile broadband connectivity is available when not connected to a facility network.

B. Fire

In the Fire scenario short term disruption of certain of the services may occur. Electricity supply may be disrupted at certain facilities, the IP-backbone may be temporarily unavailable. These outages are like a small fire that could be addressed and contained at a local level, therefore the name Fire for this scenario. For the facilities the Fire scenario includes areas within the facilities where UHF radio coverage is not available. For the convoy the Fire scenario includes areas where commercial broad-band networks are not available.

C. Drought

In the Drought scenario longer term disruption will be the order of the day. This could be large electricity outages for substantial periods (no electricity for 70% of each day), or a total breakdown of the IP-backbone. The Drought scenario cannot be addressed at a local level only. Within the context of the persistent communications system the causes of this scenario cannot be fully addressed at a local level on a continuous basis.

D. Apocalypse

In the Apocalypse scenario none of the standard services are available. Long term disruption that cannot be recovered will occur. A cause of such disruption could be for instance a nuclear detonation in the atmosphere causing a massive electromagnetic pulse [1] destroying most electronic devices.

IV. System Design

A. Green Pastures

The system design starts with the Green Pastures Scenario. The basis is devices that provide a combination of Trunked Repeater based UHF Radio communications, Wi-Fi broadband connectivity and 4G Broadband connectivity when outside the local radio and wi-fi coverage.

In the Green Pasture scenario, the facilities are connected via the IP-backbone. For the convoy a similar configuration is provided with an IP-backbone provided via the 4G network to provide the trunk connectivity. High bandwidth non-geostationary satellite communication could also be added in this scenario to provide further mobility and bandwidth [2].

B. Fire

The first provision for the Fire scenario is to provide short term uninterruptable power systems to keep the communications components powered during short term electricity problems.

Key components of the communication system are placed into separate racks and provided with short power backup.

The Fire scenario may also cause the IP-backbone to cause the radio trunk to breakdown for short periods. The system is designed such that the local repeater sites will still be able to operate independently whilst this is the case. In this scenario a satellite link could be used to provide the IP-backbone. This will however require that certain limitations be placed on the inter-site communications in order not to saturate the satellite carrier.

The Fire scenario also include other short-term events which could include a terrorist attack or a chemical explosion. In such cases the use of the 4G network could drastically increase as everybody is attempting to communicate. As indicated by [4] the success rate of a call is lowest when the traffic density is the highest, therefore the probability of loosing of the use of 4G as a communications means is high.

For the convoy loss of connectivity to the national control centre when loosing 4G backbone connectivity is not acceptable. A Satellite communications-on-the-move solution is added to the main convoy vehicle to provide the backbone connectivity in the case of no 4G service.

C. Drought

For the Drought scenario the IP-backbone may be unavailable for long terms. A replacement for the normal IP-backbone would therefore be required.

For the facilities fixed satellite communications is an option. Various options exist for the management of bandwidth across the facilities with shared bandwidth usage accounts. This reduces the overall operational cost. Long term power supplied to the base stations at the facilities must be provided. This is possible utilizing a solar with battery backup system.

In the Drought scenario, power within the whole of the country would be a problem. It is important to understand the impact on the satellite ground station. If the satellite ground station is within the country, then long term power could be an unacceptable risk. The solution used in the system design is to have the ground station situated out of country. This does have an impact on the latency of the communication. The impact is however small (<10% based on test performed) enough not to have a significant impact.

D. Apocalypse

In the Apocalypse Scenario none of the design elements of the previous scenarios would be operational. To still provide a minimal level of functionality the design elements must have been protected against the apocalyptic event. Some apocalyptic events cannot be addressed e.g., large meteorite strike but such events would also be life-ending. For a large-scale electromagnetic event the design element included is that of an HF radio capability. The HF radio's together with a limited power supply will be stored in a faraday cage protecting against the electromagnetic pulse. The radios can then be removed from storage in used to provided limited voice capability.

E. Integration

It is not always simple to explain and convince a user community that all the different elements are necessary to create the complete capability. It is necessary to provide the trade-offs between providing a high-level of functionality and the graceful degradation of the system when certain less than ideal situations occur.

Integrating all these elements into a complete System-of-Systems takes careful planning.

V. Results

A. Proof-of-Concepts

A number of proof-of-concept (POC) implementations were done to verify the performance of certain elements of the system. The POC implementations were also used to indicate the level of performance and functionality that could be delivered to the end-user.

POCs were done on satellite communications on-the-move, IP-based radio communications using a cellular phone application, fixed satellite communications and radio jamming detection.

The satellite communications on-the-move POC made use of a geostationary solution that always provided >4MB/s bandwidth. This was sufficient to provide the required services.

During the POCs the benefit of the scenario scaled implementation was verified and demonstrated to the end-user.

B. Decision Making

As the cost implication of the full-scale system is substantial it is necessary to motivate the various elements to decision makers that are not knowledgeable regarding the technology and therefore have queries regarding the number of elements that are included in the full design. The increased number of elements, from a simple design, is only seen as a cost increase.

Utilising the scenarios and the different technologies and elements that contribute to the functionality within the various scenarios provide a means of explaining the reason and requirement for the different elements. This enabled the decision makers to better understand and thereby approve the design without requiring them to understand the technology in detail.

VI. Conclusion

The scenario based approached provided a good basis for identifying various system elements necessary to provide acceptable performance over a wide range of use cases.

The scenario approach provided a means to motivate to decision makers, who may not understand the technical aspects, as to the purpose of a diverse set of options.

The scenario approach further influenced the implementation plan in terms of managing the deployment of the system depending on the perceived probability of a scenario occurring.

References

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