Rapidly Deployable Network System for Critical Communications in Remote Locations

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***Abstract*—This paper presents a transportable and rapidly deployable network system, which can be used to provide local voice, video and data connectivity for critical communications in remote locations and Internet connectivity through commercial mobile network, if available. The network is a stand-alone system, which is independent of external electricity and Internet. It is built with commercial off-the-shelf equipment and software. This paper presents trials of a local tactical voice service, a TETRA-compatible push to talk application, and Licensed Shared Access evolution spectrum manager along with radio signal measurements on 700 MHz and 2300 MHz frequency bands.**

***Index Terms*—Rapidly deployable network, field trials, critical communications, public safety, Long term evolution, 5G, land/sea path propagation and coverage, dynamic spectrum access, Licensed Shared Access evolution.**

I. Introduction

Most of the authorities, especially within public safety, currently use dedicated radio networks for critical communications. Typically, public safety communication services are narrowband professional mobile radio (PMR) systems, such as terrestrial trunked radio (TETRA) in Europe. The demand within the public safety is however shifting towards broadband services, such as video and multimedia, as they can provide useful information in many critical scenarios. As the dedicated narrowband PMR systems fail to meet this demand, the trend is going towards commercial mobile broadband networks, such as 3GPP long term evolution (LTE) and 5G technologies [1].

A major advantage involved in using commercial mobile broadband networks is the economies of scale achievable with them when compared to existing public safety communication technologies [2]. Commercial mobile radio networks are a cost-effective option for critical communications due to a large ecosystem and a wide selection of affordable user equipment (UE). In Finland, Virve 2.0 project is currently defining requirements for commercial operators who will provide a 3GPP standard based mission critical (MC) mobile broadband service for the Finnish Public Protection and Disaster Relief (PPDR) community and other relevant user groups during 2020's [3].

The network coverage is a critical requirement for critical communication networks. In remote locations, where the commercial network may not be available at all or is temporarily unavailable, transportable and rapidly deployable networks (RDNs) could be used to provide the required network coverage. However, providing a backhaul connection to the Internet can be a challenge for RDNs.

The trials described in this paper demonstrate a rapidly deployable LTE-based network built using only commercially available devices and software. The network has a local evolved packet core (EPC) to provide LTE Isolated E-UTRAN Operation for Public Safety (IOPS) [4] type of connectivity where no backhaul connection to an external EPC is needed. Our RDN is designed to provide local voice, video and data connectivity for critical communications and Internet connectivity through commercial mobile networks (when available). The main features of the system are the following:

- Transportable.
- Rapidly deployable; typically 15 to 45 minutes depending on the system complexity.
- Stand-alone; independent of external electricity and Internet.
- Built with commercial off-the-shelf equipment and software.

The terminals connected to the network can communicate between each other (audio, video streaming, etc.) even without a backhaul connection, as the used EPCs of the RDN do not require a connection to the Internet.

The trials were conducted in Turku archipelago in Finland. The location is shown in Figure 1. The ferry route between mainland Heponiemi and Kannvik is illustrated with a black line. Link distances with up to 15 km sea-land propagation path were trialed using a towable person lift as the base station antenna mast with a maximum height of 27 meters above sea level.

The trials consisted of radio signal measurements on 700 MHz and 2300 MHz bands and application testing of commercially developed solutions: Bittium Tactical Voice Service (TVS) [5], Airbus Push to Talk application [6] and Fairspectrum Licensed Shared Access (LSA) evolution Spectrum Manager. LSA evolution is a framework which is currently being developed to provide user priorities and more dynamic overall approach to access shared spectrum resources than the somewhat limited and static LSA framework developed for 2300 MHz band can provide [7]–[11].

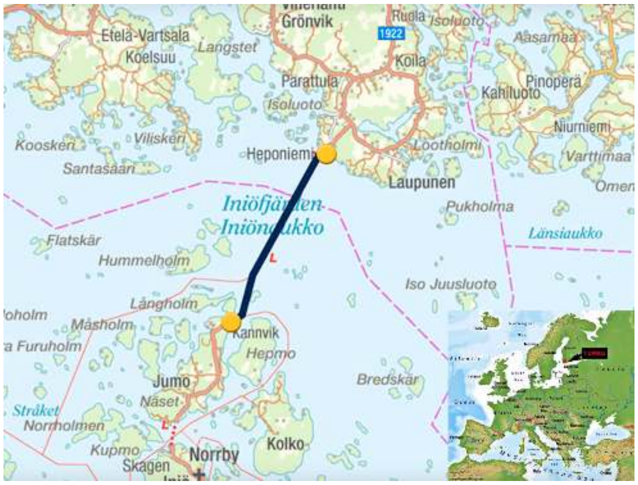

Fig. 1. The measurement location in Turku archipelago and the location of Turku in Europe.

The rest of the paper is organized as follows: Section II describes the measurement scenario and setup, Section III the measurement results, Section IV the future improvements for critical communications in 3GPP 5G, and Section V concludes the paper.

II. The measurement scenario and setup

A high-level illustration of the trial system is shown in Figure 2. The upper right corner Kustavi coast corresponds to Heponiemi of Figure 1, while the lower left corner Iniö island area corresponds to the Kannvik area of the previous figure. An eNB operating at the 700 MHz band was installed on the Kustavi coast. The eNB and antenna installation in a person lift is shown in Figure 3. The antenna has a 13 dBi gain and covers a 60-degree sector in the direction of the ferry route and Iniö island. 700 MHz terminals were used to study the RDN coverage and data rate onboard the ferry and on the island. A 700 MHz mobile router was used to route the Internet traffic to a 2300 MHz eNB on the Iniö island, i.e. the 700 MHz link was used as a backhaul for the 2300 MHz network. The 2300 MHz eNB was then used to provide local connectivity to the terminals on the Iniö island and its vicinity. More detailed block diagrams for the TVS and PTT trials are shown in Figures 4 and 5.

The following equipment was used in the trials:

700 MHz equipment, Band 28:

- eNB: Nokia APT700 MiniMacro, 2 x 20 W
- Cumucore EPC
- Antennas: 13 dBi sector panel, +/- 45 degrees polarization, height 27 m over sea level
- Terminals: Bittium Tough Mobile SD42, Samsung Galaxy 8 and 9
- Routers: ZTE MF286A, Zyxel LTE4506-M606

2300 MHz equipment, Band 40:

- eNB: Nokia Pico, 2 x 250 mW
- Bittium Lite EPC
- Antennas: 2 x multimode monopole antenna; the first had a 12 dBi gain with a reflector, and the second a 2 dBi gain in omni mode. Antenna height 6 meters over sea level
- Terminals: Samsung Galaxy 8 and 9
- Routers: Zyxel LTE4506-M606

A tactical voice service was trialed with Bittium TVS server co-located in the EPC. VoIP calls can be made to other users connected to the same EPC using a VoIP software, as illustrated in case 1 in Figure 4. VoIP calls can also be made through two separate TVS-servers which configure automatically routing for calls between the TVS servers to clients. This scenario with two TVS servers is shown as case 2 in Figure 4. The TVS can be operated without an Internet connection, and thus these trials were conducted without connection to Internet or external services. This system could be further expanded by adding more eNBs and TVS servers to create a mesh-type network to cover a wider geographical area.

When an Internet connection and a connection to Airbus PTT server is available, the Airbus PTT software can be used to communicate to other terminals with the same PTT software in any networks with Internet connectivity. Figure 5 shows two cases that were trialed; first case was with terminals within the coverage area of 700 MHz eNB and the second case with terminals communicating between two separate eNBs and networks on the 700 MHz and 2300 MHz bands.

The connection to the Airbus PTT server allows instant group communications with any users in the same communication groups, even if they are using a TETRA network and terminals instead of Airbus PTT application on LTE. The possibility to combine TETRA networks and terminals and LTE smart devices with Airbus PTT application gives flexibility to arrange PPDR services in a cost-efficient way. The Airbus PTT application is shown in Figure 6.

The LSA evolution Spectrum Manager was used in these trials to control and dynamically manage the priorities of the transmissions in the 2300 MHz band. Thus, the trials simulated a scenario where the spectrum for critical communication transmissions is prioritized over the other transmissions within the band. This means that the lower priority transmissions can be moved to other parts of the spectrum or completely shut down when the higher priority critical communications need the spectrum resources of the lower priority transmissions. The LSA evolution Spectrum Manager was integrated to both the Bittium TVS and Airbus PTT systems, as can be seen from Figures 4 and 5.

III. Radio signal measurements

The main focus of the RDN trials was to integrate all the required components into the RDN system to enable the trialing of the TVS, PTT and LSA evolution Spectrum Manager systems in a remote archipelago location. The radio signal measurements were thus not the main focus of these trials, but naturally some measurements were conducted and are briefly discussed here.

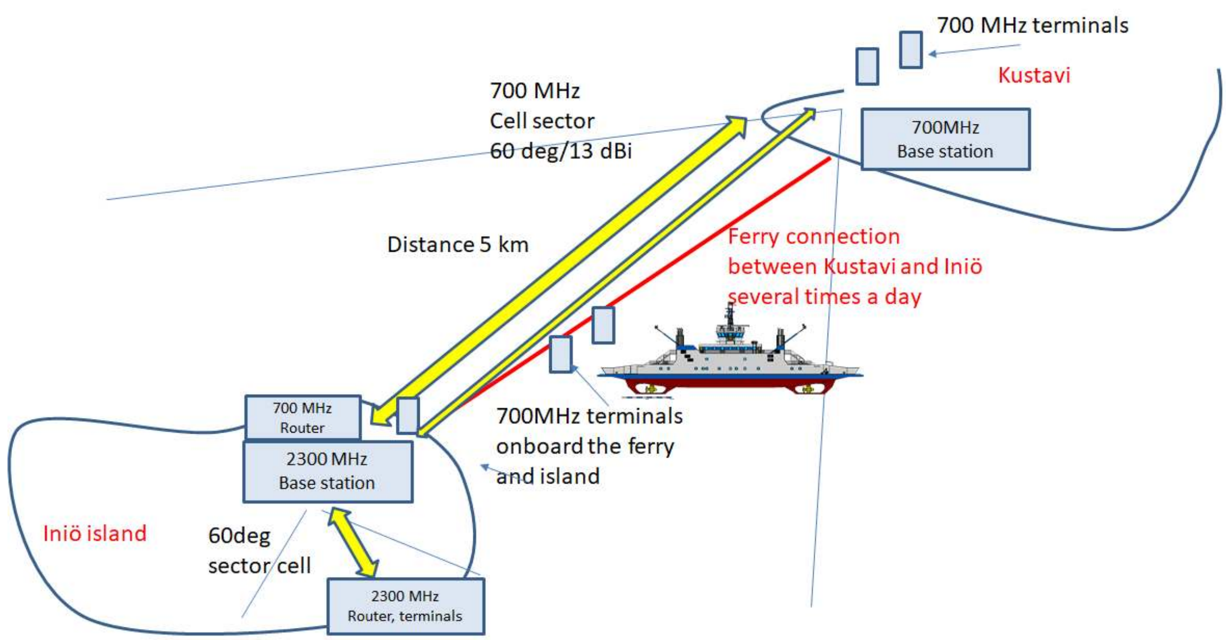

Fig. 2. High-level illustration of the archipelago RDN trial arrangement.

Fig. 3. The 700 MHz transmission antenna installed to a person lift at Kustavi shore.

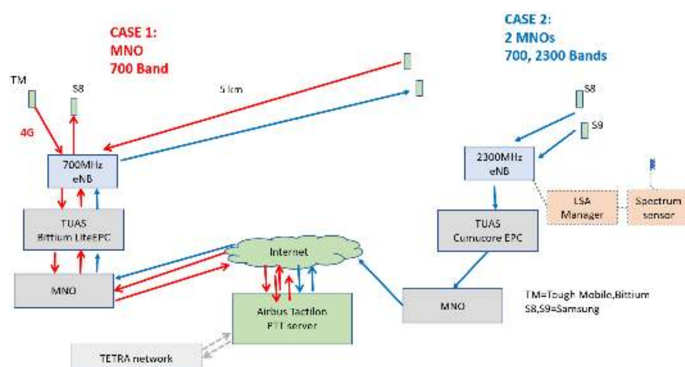

Fig. 5. Airbus Push to talk system trial block diagram.

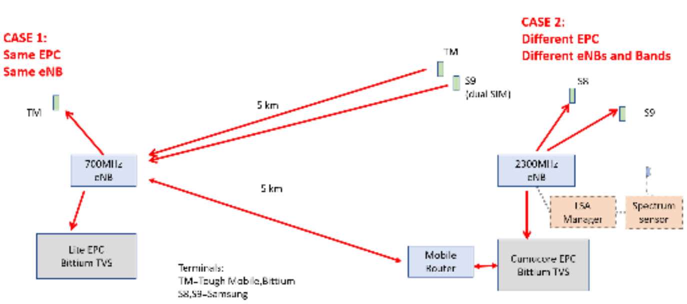

Fig. 4. Bittium Tactical Voice system trial block diagram.

We successfully used the 700 MHz link to transfer audio and high definition video from the trialed applications over distances up to 15 km. The 2300 MHz network was a low effective isotropic radiated power (EIRP) and low mast height vehicle mounted installation to provide connectivity only for very small areas with a coverage up to few hundred meters. Maximally LTE can achieve a coverage of around 100 km in maritime environments [12].

Figure 7 shows Speedtest results from two terminals. The terminal on the left is connected to the 700 MHz eNB, which is connected to a router with an access to a commercial 4G network. The terminal on the right is connected to the 2300 MHz eNB, which uses the 700 MHz connection as its backhaul to get Internet access. The effect of this additional hop can be seen from the degradation in downlink and uplink speeds

Fig. 6. Airbus Push to Talk application.

and higher ping and jitter. The connection to the commercial Internet from the 700 MHz eNB is the limiting factor in these measurements, as Speedtest measures the connection quality and speed to a server in the Internet. The QoS and data rates were sufficient for all of the tested applications.

Fig. 7. Speedtest results on terminals connected to the 700 MHz eNB (on the left) and to the 2300 MHz eNB.

Figure 8 shows received signal strength indication (RSSI) measurement results on the 700 MHz band from a mobile terminal located inside a car in the lower car deck of the ferry. The RSSI values measured during the 5.5 km ferry route are illustrated on the right side of the figure and the map with RSSI value heat map on the left side of the figure. There is some fluctuation in the beginning of the measurement as the ferry makes a 90-degree turn after leaving the harbour and the car deck is shadowed by metal side walls. Stern is open and directed towards the eNB antenna after the initial turn. Bow is also open and towards the eNB antenna when the ferry is approaching on the return route. The measurements show a clear trend where the RSSI gradually drops when the distance increases. The RSSI level is around -85 dBm at the starting point of the ferry in the north when the ferry is located next to the eNB installation on the coast, and it gradually decreases to around -110 dBm during the 20-minute ferry ride.

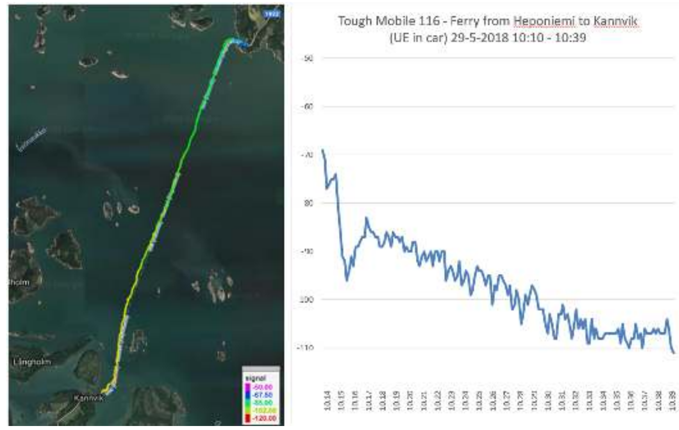

Fig. 8. RSSI measurements conducted on a mobile terminal inside a car on the lower car deck.

Figure 9 shows RSSI measurement results on the 700 MHz band from a router located on the upper passenger deck, about 5 meters above the sea level. The briefcase where the router and the measurement system are installed on the deck can be seen on the left side of the figure and the 27-meter antenna mast can be seen on the background. The RSSI values follow a similar trend as in the previous measurement, but the values range from around -70 dBm to -95 dBm and are thus about 15 dB higher when compared to the results from inside a car at the lower car deck.

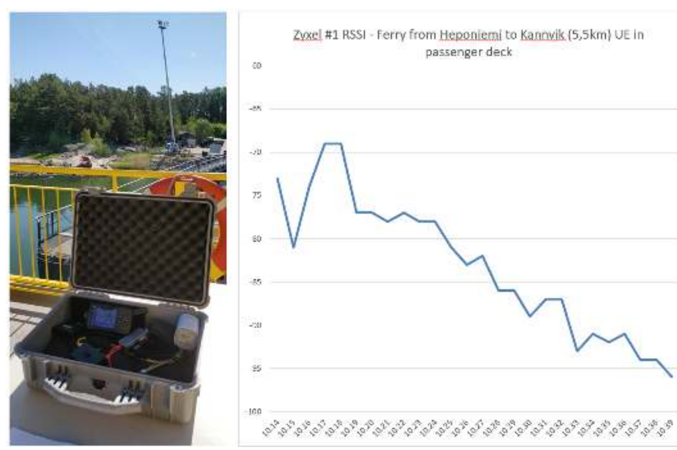

Fig. 9. RSSI measurements conducted on a router on the upper passenger deck, 5 meters above the sea level.

IV. Future improvements for critical communications in 3GPP 5G

This section briefly discusses future developments which could improve the operation of 3GPP-based critical communications networks. A wider overview on the history and future of critical communications in 3GPP networks is available in [1].

5G makes it possible to prioritize the critical communication transmissions within a commercial mobile network through network slicing and quality-of-service (QoS) control [1]. This will be a main feature required if critical communications are to be transmitted over commercial networks. The LSA evolution trials in this paper considered the priority of critical communications also with respect to the spectrum used by the critical communication transmissions. In a disaster scenario it is essential that the physical spectrum access for RDNs can be guaranteed through LSA evolution or similar system.

The 3GPP technologies also include a broadcast capability, which will be essential to critical communication networks when they are streaming situational awareness information to a large number of users. For example, high definition video transmissions through unicast could congest the network [13]. The broadcast capability in LTE, called evolved Multimedia Broadcast Multicast Service (eMBMS), is somewhat static and limited [14]. Thus, a more flexible point-to-multipoint (PTM) framework, which integrates point-to-point (PTP) and PTM modes under one common framework and enables dynamic use of PTM to maximize network and spectrum efficiency, is under development [15]. This new PTM framework will be important in avoiding network congestion when broadcasting situational awareness information in future 5G critical communication networks.

Spectrum sensing technologies could also be used to validate the LSA spectrum information and to select the best channel if the LSA system is not available.

V. Conclusions

The RDN system introduced in this paper indicates that it is possible to build a transportable, rapidly deployable and standalone LTE Network for critical communications using commercially available hardware and software products. The network is independent of external electricity and Internet and can be built in 15 to 45 minutes, depending on the required system complexity.

The trials conducted in the built RDN included i) a Tactical Voice Service where no Internet connection is required, ii) a PTT application, where Internet connection is required, which could also connect to users in TETRA network, and iii) LSA evolution Spectrum Manager to control and dynamically manage the priorities of different transmissions, which thus allows to prioritize the mission critical transmissions over the other transmissions in the band.

Further trials are planned to investigate the coverage and QoS with for example different IoT technologies, such as Narrowband IoT (NB-IoT) and LTE-M, and 5G New Radio.

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