Towards Moving Public Safety Networks

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Abstract

Fourth Generation Long Term Evolution (LTE) has been selected by US federal and EU authorities to be the technology for public-safety (PS) networks that would allow first responders to seamlessly communicate between agencies and across geographies in tactical and emergency scenarios. From Release 11, the Third-Generation-Partnership-Project (3GPP) has been underway to develop and specify dedicated, nationwide public safety broadband networks that will be scalable, robust and resilient and can address the specific communication needs of emergency services. In this realm, the requirements and scenarios for isolated Evolved Universal Terrestrial Radio Access Network (E-UTRAN) with no or limited backhaul access to the core network are still in progress. In this article, we survey possible public safety use-cases with the induced network topologies, current status of the 3GPP standards and highlight future challenges. We further elaborate on the need to support mobile backhauling in moving-cell scenarios and describe two LTE-based solutions to enable dynamic meshing among the base stations.

I. INTRODUCTION

A. Motivation

Long Term Evolution (LTE) specified by the 3GPP is becoming the technology reference for 4G cellular networks, as it is increasingly adopted by all major operators all over the world. LTE is now rising to the challenge of addressing several issues (e.g. cellular networks' capacity crunch, ultra-high bandwidth, ultra-low latency, massive numbers of connections, super-fast mobility, diverse-spectrum access) that speed up the pace towards 5G. Moreover, LTE is expected to be an important part of the 5G solution

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for future networks and also play an essential role in advancing Public Safety (PS) communications. In US, LTE has been chosen up as the next appropriate communication technology to support public-safety and it is likely to be the same in EU soon. Thus, several vendors (e.g. Ericsson, Nokia-Alcatel, Huawei, Cisco, Motorola, Thales) are now starting to propose LTE-based public-safety solutions and some of them have been put to real field experimentation.

While existing PS solutions (e.g. Project 25 (P25) and Terrestrial Trunked Radio (TETRA)) are mature and provide reliable mission-critical voice communications, their designs cannot meet the new requirements and the shift to higher bandwidth applications. In addition, LTE system is a commercial cellular network and was not suited in the initial 3GPP releases to support PS services and the corresponding requirements like reliability, confidentiality, security, group and device-to-device communications. Therefore, the raising question is whether LTE suffices to be an appropriate solution for PS networks. To address those issues, 3GPP has started to define the new scenarios that LTE will have to face and it has released several studies on proximity-based services, group and device-to-device communications, Mission Critical Push-To-Talk (MCPTT), and Isolated E-UTRAN. These studies define the requirements regarding user equipments (UEs) and evolved NodeBs (eNBs - LTE base stations) to provide PS services depending on the E-UTRAN availability and architecture.

Particularly, the studies on isolated E-UTRAN target use-cases when one or several eNBs have limited or no access to the core network (evolved packet core - EPC) due to a potential disaster, or when there is need to rapidly deploy and use a LTE network outside of the existing infrastructure coverage. However, 3GPP studies do not define how such isolated eNBs of a single set should communicate together, and leave that to the use of other technologies and vendor specific solutions.

B. Contribution

In this article, we discuss possible directions and challenges to evolve the LTE network architecture towards 5G in order to support emerging public-safety scenarios. Starting from the current status of standards on mission-critical communications and focusing on isolated E-UTRAN case, we delineate two innovative solutions that allow for inter-connection of eNBs using LTE, while qualifying the requirements defined by 3GPP for PS scenarios. Such solutions present several advantages when compared to dedicated technologies (e.g. WiFi, proprietary radio frequency (RF) links), in that they support network mobility scenarios, topology split and merge while being cost effective.

The first solution utilizes legacy UEs and evolves them in order to operate as active elements within the network (UE-centric), thus being capable of associating with multiple eNBs and restoring the disrupted links between them. The second solution relies on extension of the eNB functionality, to allow it to detect and connect directly to neighboring eNBs by encompassing multiple virtual UE protocol stacks (network-centric). These two solutions evolve and re-store already existing and potentially disrupted wireless air-interfaces such as Uu (eNB-UE radio interface), Un (eNB-relay radio interface), X2 (inter-eNB logical interface). They create connectivity links among eNBs that can be used to form dynamic mesh networks allowing to extend the size of isolated E-UTRAN in fixed and mobile scenarios.

II. USES CASES AND TOPOLOGIES

PS users and first responders encounter a wide range of operational conditions and missions. To effectively address them, they need to rely on sufficient voice and data communications services. While voice services have already been used in tactical communication systems (e.g. TETRA and P25), the absence of a technology that could offer sufficient data services left their use in the background.

In nominal conditions, a nation-wide broadband wireless PS network relies on a wired network supporting fixed wireless base-stations (BSs) providing planned coverage and bringing services to mobile entities (e.g. hand-held user equipment (UEs) or vehicle integrated devices) relying on seamless access to the core network. A key requirement for the network is that it must be robust, reliable and non-prone to malfunctions and outages. Despite that, it may not survive against unexpected events such as earthquake, tidal waves and wildland fires, and it may not cover distant lands due to costly deployment.

Fig. 1 illustrates six different topologies corresponding to possible use-cases that public-safety users may encounter depending on the operational situation. These six topologies differentiate based upon four criteria: (*i*) availability of the backhaul link (access to the core network from the BS), (*ii*) BS inter-connections, (*iii*) BS mobility and (*iv*) BS availability (UEs on- or off-network). In the nominal case (case 1 in Fig. 1), BS are fixed and benefit from a planned coverage as they receive complete services support, experience full access to the core network and to the remote public-safety services with no intermissions (e.g. continuous link connectivity with operation center, monitoring, billing). Therefore, network can provide nominal access to PS UEs and this case refers to the majority of operations (e.g. law enforcement, emergency services, fire intervention) occurring in covered cities and (sub)-urban environments where the network deployment has been previously designed and planned, and services are provided within a large coverage expansion.

In the case of backhaul link failure due to faulty equipment, power outage or physical damages on the backhaul wires or RF antennas, the core network may not be fully accessible anymore to the fixed BSs (cases 2 and 3). However, depending either on the type and the position of failure, or on the availability

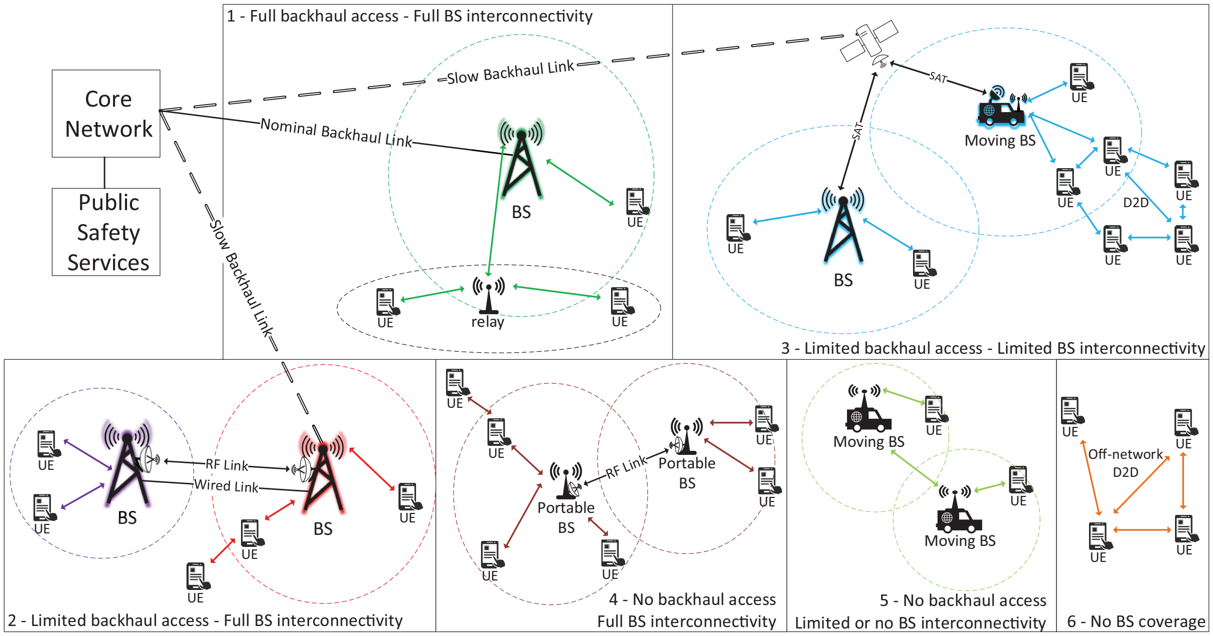

Fig. 1. Public safety use cases. *Case 1*: Planned Network with Fixed BSs Deployment and Backhaul Connectivity. *Case 2*: Planned network with fixed BSs deployment and limited backhaul connectivity. *Case 3*: Network with fixed BSs deployment and moving cells with limited backhaul connectivity assisted by satellite links, proximity services and device-to-device communications. *Case 4*: No Backhaul access in an unplanned network deployment of portable BSs. *Case 5*: Moving cells in an unplanned network deployment. *Case 6*: Missing BS coverage and proximity services.

of backup solutions (for instance satellite backhaul as given in case 3)[1], the BSs may still keep adequate inter-connectivity to each other. Portable BSs (fixed once deployed) can be exploited in order to provide coverage on site, where the fixed BSs have not been fully deployed yet or have faulty operation (case 4). In the same way, moving BSs can be utilized in a more dynamic fashion (e.g. for a fight against a fast moving forest wildfire, in vehicular communication being on land or at sea [1], [2]) where it is not possible to plan inter-BSs links (case 5). In these cases of portable or moving BSs use, it can be hard or impossible to maintain a good connectivity with the macro core network (cases 3, 4 and 5).

Finally, it is likely that due to mobility, users would get out of the coverage servicing area provided by the BSs (cases 2, 3 and 4), or that in-time service provisioning to users would fail due to intense mobility (case 6). Therefore, due to their own inherent limitations (access to the core network, inter-nodes

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[1] In such a case, the communication protocol is usually improved by performance-enhancing proxy (PEP) as specified in IETF RFC 3135 and RFC 3449.

connectivity, BSs and UEs mobility), all previous topologies may not be able to provide the same services with the sufficient level of quality to the users. For instance, the billing and monitoring services might not be available on some cases. Nevertheless, PS users must be able to use vital services like voice and data group communications in all situations regardless of network topology dynamics. That is why PS wireless communications cannot rely solely on a planned network of fixed BSs.

III. STANDARDS DEVELOPMENT

The simmering interest of public authorities in LTE for public-safety use have encouraged 3GPP to tackle this subject and to evolve LTE specifications. Especially, significant standardization activities have been conducted after the creation of the First Responder Network Authority (FirstNet) in US. As it is illustrated in Fig. 2, the first work dedicated on public-safety was launched in 3GPP Release 11 along with the introduction of high power devices operating in Band 14 (used in US and Canada for PS) to extend the possible coverage servicing area. Since then, several work items have been defined in Release 12 and 13 to study and address the specific requirements of a broadband public-safety wireless network, the not

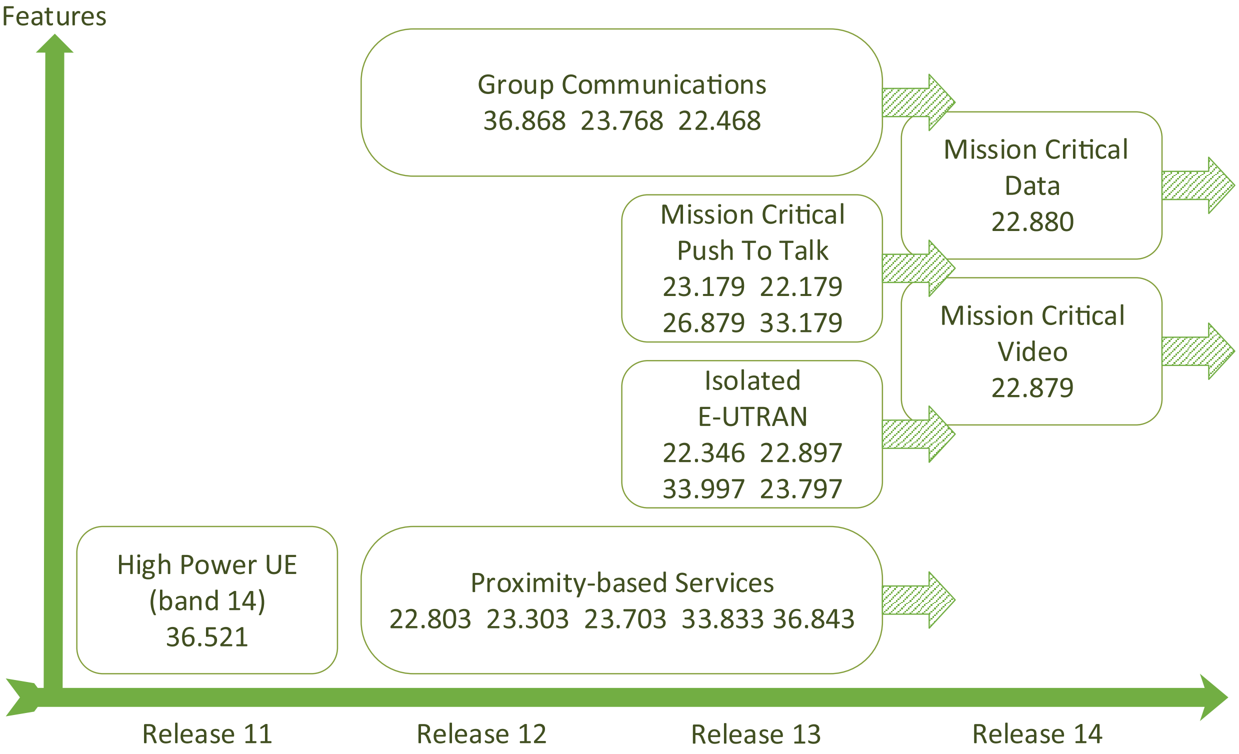


Fig. 2. 3GPP Public-Safety oriented work items.

least of which are given below:

1) Guaranteed access: PS network should be accessible at any time;
2) Quality of Service (QoS): guaranty and priority should be ensured for critical calls;
3) Reliability: PS networks should provide the services as defined with no interruption when online;
4) Resiliency: the PS network should be able to evolve with technology advancements and changes to operational requirements;
5) Roaming: UEs should be able to seamlessly use the deployed PS network while also commercial networks in case of unavailability of the first one;
6) Spectrum efficiency, Capacity, Coverage: spectrum has to be effectively shared to provide the required capacity and coverage;
7) Talk around/simplex: users should be able to communicate even in case of broadband network unavailability or disruption.

The gaining momentum of LTE networks around the globe has relied on its architecture to provide packet-based network services which are independent from the underlying transport related technologies. A key characteristic of the LTE architecture is the strong dependency of every deployed Base Station (known as eNB) on the global packet core network (EPC) for all the type of services that are provided to the covered UEs. However, this feature prevents UEs from a seamless communication service when an eNB is getting disconnected of the EPC as eNB service to the UEs is interrupted even for local communications. To tackle the aforementioned shortcoming, 3GPP has launched two series of work items: the first one refers to device-to-device communications for enabling "Proximity-based services" (ProSe), and the second one refers to the continuity of service for PS UEs by the radio access network (RAN) and eNBs in the case of backhaul failure for enabling operation on "Isolated E-UTRAN".

As it has been defined in 3GPP technical specification (TS) 22.346, isolated E-UTRAN aims at the restoration of the service of an eNB or a set of inter-connected eNBs without addressing their backhaul connectivity. The goal of Isolated E-UTRAN Operation for Public Safety (IOPS) is to maintain the maximum level of communications for public safety users when the eNB connectivity to the EPC is either unavailable ("no backhaul") or non-ideal. Isolated E-UTRAN can take place on top of Nomadic eNBs (portable BS, c.f TS 23.797) deployments or on top of fixed eNBs suffering failures. It should support voice and data communications, MCPTT, ProSe and group communications for PS UEs under coverage as well as their mobility between BSs of the Isolated E-UTRAN, all while maintaining appropriate security.

Subsequent to TS 22.346, technical report (TR) 23.797 provides a solution to the “no backhaul” IOPS case relying on the availability of a local EPC co-located with the eNB or on the accessibility of the set of eNBs. PS UE(s) should use a dedicated Universal Subscriber Identity Module (USIM) application for authentication and use classical Uu interface to connect to these IOPS networks. If an eNB cannot reach such local EPC, it must reject UE connection attempts. However, the aforementioned solution does not address issues on scenarios with non-ideal backhaul connectivity. Moreover, requirements on the inter-eNB link connectivity are not specified, even though the operation for group of inter-connected eNBs is defined.

In this article, we advocate the need for novel inter-eNB wireless connectivity as a key for the efficiency of isolated E-UTRAN operation that would allow broadening the network and enhancing the level of cooperation between adjacent nodes, leading to better service provision to the users. We also consider moving cells and meditate on eNB mobility in a potential split-and-merge network which is often encountered by (highly) mobile PS entities.

IV. FUTURE CHALLENGES IN PUBLIC SAFETY

Given the wide range of applications, PS communications must be able to provide to a large extent flexibility and resiliency. Being able to adapt under various circumstances and mobility scenarios that are characterized with disrupted communication links (e.g. damaged S1 interface and no EPC network access) and volatile infrastructure operation is of utmost importance. Although there is an increasing interest on the development of public safety solutions for isolated E-UTRAN scenarios both by industry and academia, there are still open challenges. Next, we discuss the not least of which.

A. *Moving Cells and Network Mobility*

In a crisis or tactical scenario, it is vital that field communications can be highly mobile, and rapidly deployable to provide network access and coverage on scene. Currently, E-UTRAN is considered fixed and detection as well as discovery of a network while moving cells are being deployed, remains unspecified. When high mobility occurs, then the problem becomes the network availability as link connections to the EPC servers are dropped. Moreover, due to the limited coverage of the moving cells as compared to fixed eNBs [1], enabling inter-cell discovery features for proximity awareness is required as a tool of network intelligence for self-healing. eNBs must be able to search for other eNBs in their proximity either directly or relying on the assistance of enhanced UEs (i.e. UEs with extended capabilities that can interconnect between two eNBs) and eventually synchronize to the most suitable one and re-establish access to the network.

B. Device-to-Device (D2D) Discovery and Communications

In the absence of network coverage (off-network case), PS UEs require to discover and communicate with each others by taking partially control of the functionality of the network [3]. UEs should be able to provide network assistance when infrastructure nodes (i.e. eNBs) are missing due to network and/or terminal mobility, or when they are unavailable due to outage and malfunctioning. In such situations, UEs are promoted to assist with time synchronization reference (e.g. based on side-link power measurement or UEs own timing), authentication, detection, network discovery and attachment functions among the others. In addition, UEs may need to request the identity of the neighboring UEs (i.e. who is here) belonging to different PS authorities, which calls for the over-the-air sensing and self-reconfiguration functionality at the UE side. What is more challenging for public safety UEs is the support of (stored) data relaying from (isolated) neighboring UEs either to other UEs (UE-to-UE relay) or to the network (UE-to-network) when they are in-coverage.

C. Programmability and Flexibility

Programmability and flexibility in future PS systems shall allow to rapidly establish complex and mission-critical services with specific requirements in terms of service quality. A high degree of programmable network components will be able to offer scalable and resilient network deployment on-the-fly without the need of previous network planning by using network function virtualization and software-defined networking. Thus, it will result in availability of open network interfaces, virtualization of networking infrastructure and rapid creation and deployment of network services with flexible and intelligent control and coordination framework. Such a control and coordination framework is required to manage the entire life-cycle of the PS network from the configuration and deployment to runtime management and disposal. This is very challenging as it has to optimize the resource allocation across multiple eNBs, to manage the topology especially during the network split and merge, and to determine the IP addressing space among the others.

D. Traffic Steering and Scheduling

The decisions about traffic steering concern control plane actions enabled to form a wireless mesh network. Selecting one or a subset of eNBs to steer the data-plane traffic allows users getting connected to the best fitted network according to their QoS requirements and the network resources availability. Aiming at overall network optimization, traffic steering techniques can be leveraged to balance the network load and satisfy carrier and user demands by properly enabling data offloading, interference management or energy saving policies. Furthermore, the control and the data plane should be decoupled as the routing decision and eNB selection are performed at the higher layers while data transfer is operated at the lower layers. Therefore, a novel mechanism to support the BS meshing by giving access to the forwarding table at the lower layers is required. It can be implemented either locally or over the network. In the former case, the forwarding table can be simply built based on the routing table. In the latter case, a software define networking (SDN) approach can be applied to interface between the control and data plane.

E. Optimization of Performance Metrics to Support Sufficient QoS

A public safety network requires provision of sufficient services when a serving eNB currently experiences interruption on backhaul connectivity. Apart of the initiation of isolated E-UTRAN operation, such as exploitation of inter-eNB connectivity links for recovery of the system connectivity, a public safety network also requires a mechanism to invoke the appropriate complementary resources (e.g. additional bandwidth, alternate communication links, complementary bearers) for self-healing operation and re-establishment of disrupted end-to-end bearers. For a more efficient operation on the network, it is important that the same mechanism makes decisions by considering not only the availability of the complementary resources, but also the indicators and the metrics that characterize communication performance (e.g. latency, throughput, spectral efficiency, etc.) upon the links and priority level assignment upon the evolved packet system (EPS) bearers.

V. TOWARDS MOVING PUBLIC-SAFETY NETWORKS

In current LTE architectures, eNBs are perceived as the active elements being responsible for the management and control of the radio access network. On the opposite, UEs are passive clients from the eNB perspective obeying certain rules and complying with the eNBs policies. Thus, eNBs and UEs relationship follows the master-slave communication model that is designed to meet the requirements of a fixed network topology. However, network mobility is increasingly gaining interest and mobile scenarios where portable or moving cells are essentially required for rapidly deployable networks, render networking elements with enhanced capabilities more-and-more attractive. We advocate the need to address those future mobility objectives as a means to meet public safety requirements in an isolated E-UTRAN operation. Towards this direction, the role of legacy eNBs and UEs should be reconsidered within the network.

Following this approach, we delineate two novel solutions that allow to realize inter-eNB link connectivity and to restore the disrupted air interface by utilizing (*i*) evolved UEs (denoted as eUEs) and (*ii*) enhanced eNBs (denoted as e2NBs). The first refers to a UE-centric network-assisted solution. UEs are assigned with enhanced capabilities of associating to multiple eNBs using multiple UE stacks, and thus interconnecting adjacent eNBs. They act as 3GPP UE terminals maintaining their initial operation and also act as a slave with respect to the eNBs perspective. The second concerns a network-centric solution. eNB stack is extended with several UE stacks, in what we call an e2NB, allowing it to discover and connect to neighboring eNBs, forming a wireless mesh network. A potential yet achievable topology is illustrated on Fig. 3, along with a concise depiction of the eUE and e2NB architectures.

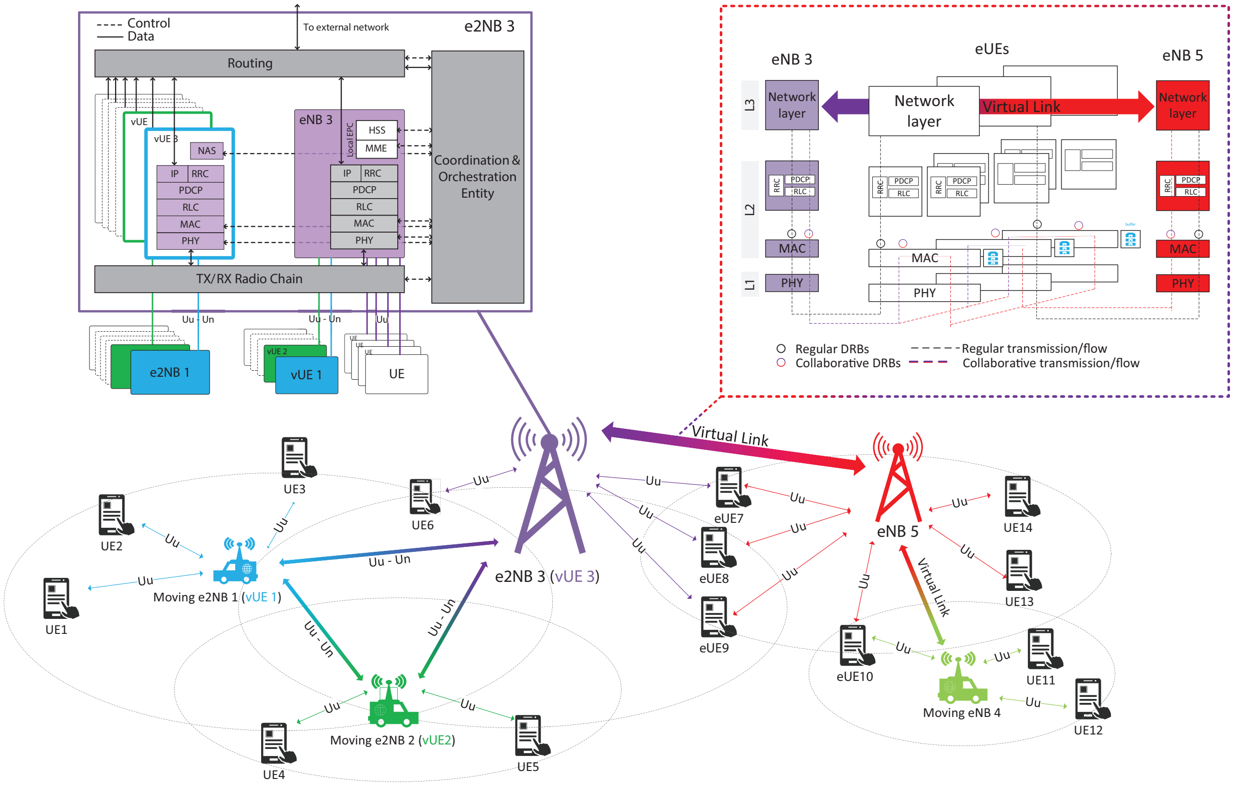


Fig. 3. eUE and e2NB architecture for public safety: meshing of isolated or moving eNBs is enabled either (*i*) by leveraging eUEs as intermediate packet forwarders (UE-centric), thus creating virtual-links between eNBs, or (*ii*) by leveraging e2NBs functionality of encompassing multiple vUEs (network-centric), thus re-storing disrupted eNB-eNB communication.

A. Evolved UEs (eUE)

Evolved UEs as legacy user equipment do, interpret the scheduling information coming from the eNB on the downlink control and signaling channels, so as to enable traffic routing and forwarding relying on the allocated physical resource blocks (RBs). Moreover, they report measurements about channel state information (CSI) and buffer status report (BSR) back to the eNB. Furthermore, eUEs have enhanced capabilities of associating to multiple eNBs and thus interconnecting adjacent eNBs [4]. As a consequence, eUEs can also be used to extend the cell servicing area and provide backhaul access to core-isolated eNBs and hence to isolated E-UTRAN scenarios. eUEs can act as intermediate nodes so as to forward the traffic originating from or destined for eNBs. They belong to the control of the radio access network (RAN) of the bridged eNBs.

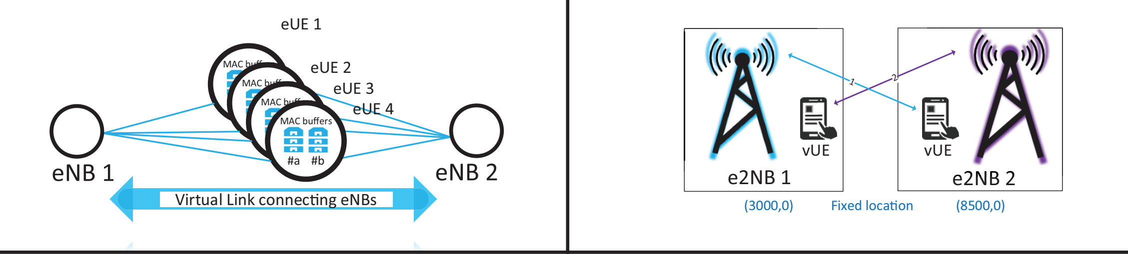
B. Enhanced eNB (e2NB)

The e2NB solution relies on the legacy 3GPP eNB and UE functions [2]. The e2NB solution consists of: (*i*) the ability to provide service to mobile UEs and maintain the legacy eNB operation as a standalone node, and (*ii*) the ability to form a wireless mesh network when it is in close proximity to other e2NBs while maintaining the service for the mobile entities. The former is achieved by extending the eNB functionality with that of core network (i.e. mobility management entity (MME) and home suscriber server (HSS)) which allows it to manage UEs and provide PS services as it is proposed by 3GPP Isolated E-UTRAN “no-backhaul” solution. The latter leverages the Uu and Un interfaces of 3GPP UE and relay node. An e2NB encompasses multiple virtualized UEs (vUEs), integrating full LTE UE stacks, and one eNB. They share the radio resources and frontend. VUEs are used to discover other e2NBs and can be on-demand instantiated to connect to the neighboring eNBs using Uu interface and UE connection procedures before switching the Un interface. The discovery and on-the-fly connection features allow it to surpass classical LTE relays [5] by enabling BS mobility and multiple connections to neighbors re-establishing inter-eNBs connectivity.

C. Evaluation of the feasibility and the impact on latency

In order to evaluate the performance of the above isolated E-UTRAN solutions in a practical and real setting, a prototype implementation of the proposed solutions was tested using the OpenAirInterface platform [6]. Specifically, OpenAirInterface is an open-source software implementation of the fourth generation mobile cellular system that is fully compliant with the 3GPP LTE standards and can be used for real-time indoor/outdoor experimentation and demonstration. After thorough experimentation, results demonstrated the feasibility of the proposed approaches, as these have been presented in works [2], [4]. Indicatively, in Fig. 4 we demonstrate two topologies for isolated E-UTRAN problem where backhaul connectivity is not present. In Fig. 4.a, four UEs are leveraged to restore the link connectivity between two eNBs. Performance evaluation results reveal (as it is shown in Fig. 4.b) a significant reduction in latency (up to 16.94%) which depends on the number of active cooperating eUEs (up to 4).

In Fig. 4.c, two e2NBs enable inter-eNB connectivity utilizing vUE operation. Two vUE-e2NB links are created allowing the use a subset of uplink and downlink subframes (SFs) from one e2NB to the other (6 scenarios in Fig. 4.d). An important finding that concerns latency performance is that whether using uplink (UL, UE to eNB) or downlink (DL, eNB to UE), the latency improves as the number of available SFs increases. More importantly DL shows significant lower latency performance overall as this is not only related on the resource allocation policy but also on the scheduling choice of using UL or DL path. Thus, flows with different QoS requirements should be mapped on the corresponding link, for instance low latency services (e.g. voice calls) should go over DL paths.


(a) eUEs re-store inter-eNB link connectivity

(c) e2NB and vUE enable inter-eNB link connectivity

(b) eUEs Performance Evaluation

(d) e2NB-vUEs Performance Evaluation

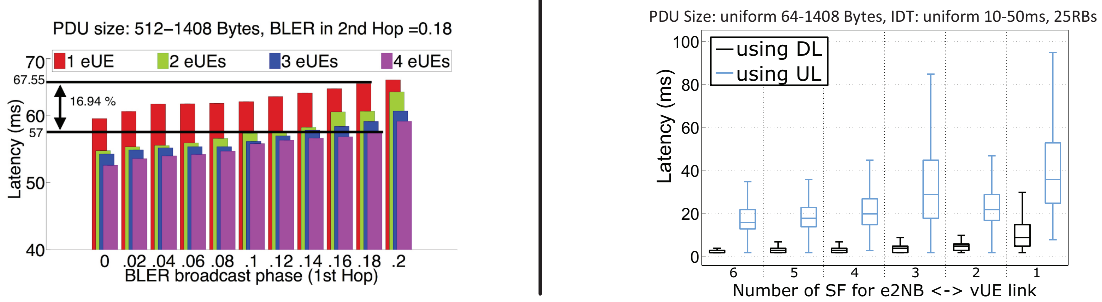


Fig. 4. Logical topology for the performance evaluation scenario in OAI: (a) four eUEs are leveraged to interconnect two eNBs, (b) Performance results for latency in eUEs scenario, (c) two e2NBs establish link connectivity using vUEs, (d) Performance results for latency in e2NB-vUEs scenario.

D. Discussion

Some research articles provide insight of solutions when no backhaul is available, providing inter-eNB connectivity thanks to WiFi links and including D2D communications that were not yet defined by the ProSe specifications of 3GPP studies [7]. Other technologies are usually used to establish wireless backhaul supporting fixed LTE networks: point-to-point (PTP) RF or free space optics (FSO) links and point to multi-point (PTMP) RF links. In the case of portable BS, satellite backhaul links are sometimes used. However, we can easily see that these wireless solutions are not adequate to the establishment of a network of BS enabling voice and data communications in moving cells scenarios.

TABLE I

MAIN CHARACTERISTICS OF BASE STATIONS BACKHAULING SOLUTIONS

BS Backhauling	**PTP/PTMP/FSO**	**SAT**	**WiFi**	**eUEs**	**e2NBs/vUE**
Frequency band	ISM or licensed	Licensed	ISM, possibly licensed	Licensed	Licensed
Link Latency	Very Low	High	Low-Medium	Low-Medium	Low
BS mobility support	No	If tracking antenna	If omni-antennas	Yes	Yes
Cost	+++	++++	++	++	+
Topology	Star/Mesh	Star	Star/Mesh	Mesh	Mesh

For instance, Table I shows the main differentiating criteria. Despite great performance, PTP and PTMP solutions usually require line-of-sight wireless connectivity with careful network planning, which make them not applicable to the moving cell scenarios. Satellite backhauling, on the other hand, provides the best possible coverage but may require dedicated tracking antennas and suffers from high cost and high latency ($\geq$200ms) that limit voice and data services [8]. WiFi solutions are promising if the higher layers and protocols allow for efficient and dynamic meshing, similar to the proposed LTE-based solutions (eUE and e2NB). However, additional dedicated equipment and antennas are needed for WiFi backhauling, thus increasing the cost of BSs. In addition, commodity WiFi works on industrial, scientific and medical (ISM) bands and thus can experience more interference compared to LTE using licensed bands[2]. Studies on commercial networks have shown that the WiFi latency is on average a bit higher and has more jitter than that of LTE although results might differ for PS networks [9]. Moreover, carrier aggregation and full duplex communications are expected to greatly increase LTE global throughput in such mesh topologies, although similar techniques could be used for WiFi.

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[2] To solve this problem, certain countries define their own licensed bands for PS WiFi.

VI. SOME REFLECTIONS AND CONCLUSION

Commoditization and virtualization of wireless networks are changing network design principles by bringing IT and cloud-computing capabilities in close proximity of network and users. This will facilitate the deployment and management of PS networks by offering a service environment so that adequate (e.g. missing) network functions and applications can be dynamically instantiated for the isolated network segments to maintain the communication, service, and application as desired [10]. Packet core network functions (e.g. MME, HSS), IP Multimedia Subsystem (IMS), routing, topology management are those network functions that can be enabled at the BS to restore the communication links. Traffic steering, video analytics, content sharing, and localization are the example of network applications that can extend the BS functions in order to preserve user service and application.

In this article, we elaborated on innovative solutions in the context of public safety networks to support an efficient isolated E-UTRAN operation. We identified the shortcomings on the state-of-the-art technology which is currently inappropriate to sufficiently deliver seamless and continuous backhaul connectivity in moving cell scenarios, thus making first responders and tactical forces be deprived of critical communications. Particularly, we indicated that in a such volatile and dynamic environment for public safety communication, (*i*) evolving UEs as active network elements to restore disrupted air-interfaces between bridging eNBs, and (*ii*) enhancing the role of legacy eNBs to encompass a dual protocol stack operation for enabling base station meshing, become of utmost importance to preserve the integrity of communication. Relying on the open challenges that pose significant requirements on the field of services provision, we outlined the not least of which and discussed related open research directions.

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