When will 5G be ready for PPDR?

True technical capabilities of 5G can only be assessed through an early dialogue between 5G developers and PPDR users. The former will test their technologies according to PPDR user needs, whereas the latter (both PPDR mobile operators and responders), will define user needs and feedback their opinions during a co-creation dialogue that will help shape 5G technological implementations and potential adaptations to standards.

The demand for 5G by the consumer market, will establish that technology as the underlying technical capability most likely to be used by Public safety responders. It is difficult to estimate when exactly this will be the case, but it is crucial that:

- Ministries of Interior and their agencies, responsible for PPDR communication services are aware of the true technical capabilities of 5G,
- Developers of 5G technology (and its enablers) understand the true functional and non-functional requirements of PPDR,
- The business case options are understood for PPDR adoption of 5G services,
- Legal frameworks, policy and regulation will support adoption for PPDR on 5G.

A report by GSMA forecasts that by 2025, 5G will account for 29% of mobile connections in Europe. Therefore, we can anticipate that the PPDR sector must be ready with full knowledge by then and prepared to adopt and evolve through 5G capabilities, if they are evaluated to be beneficial.

Many current press articles cite the early deployments of 5G signifying the race to be the best, first, in order to solidify vendor and operator market positions. This is not the primary concern. Our proposed project will facilitate this dialogue between developers of these new potential 5G capabilities and the key stakeholders in the PPDR mobile operator user community.

This paper considers new 5G capabilities in their intended and beneficial form. However, technical validation in real situations and PPDR end user evaluation are crucial to make informed decisions over the coming years.

Please note that the PSCE project BroadWay has the objective to work with industry to solve the problem of pan-European mobile broadband for public safety to provide operational mobility across Europe in the 2025 timeframe and once broadband capabilities are available in each country. Our 5G related proposal focuses on the mobile broadband capability that may be the topic of future evaluation of mobile networks. Therefore their goals are uniquely different both technically and in a temporal manner, despite the common topic area. PPDR users are crucially common to both activities.

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When will 5G be ready for use by PPDR?

David Lund
Public Safety Communication Europe
Brussels, Belgium
david.lund@psc-europe.eu

Daniel Corujo
Instituto de Telecomunicações and
Universidade de Aveiro
Aveiro, Portugal
dcorujo@av.it.pt

Rui L. Aguiar
Instituto de Telecomunicações and
Universidade de Aveiro
Aveiro, Portugal
ruilaa@ua.pt

***Abstract*— It is imperative that we bring early feedback of the PPDR arena into 5G technology developments, and given its specific nature, such an effort must also be performed in a coordinated way. Given the current standardization status and technological base of 5G experimental platforms, now is the time to act and impact the design and adoption of future PPDR broadband mobile systems. Furthermore, the existence of commercial trials increases the possibilities of geographical and stakeholders' reach, way beyond early 5G end to end test platforms. Although some probing activities have recently started, it is important to seriously assess and explore the 5G technology capabilities now, developing knowledge, technology and experiences that will prevent these PPDR critical operations from falling back to only being able to use basic services, such as voice or short amounts of telemetry data.**

I. Introduction

Public Protection and Disaster Relief (PPDR) composes the most critical societal impact and life-affecting vertical use of 5G, with the most demanding requirements in terms of reliability, availability and scaled quality.

In recent years it has been recognised that Public Safety First Responders should adopt broadband mobile communication technology to allow access and sharing of broadband data. This will allow our responders the best mobile communication capability in the face of crime, terrorism and in the response to disaster.

Voice is currently the primary accepted mode of communication for public safety responders. This is the current state, primarily due to the fact that technology currently used in the majority of deployments are equivalent to 2G mobile communication. It is trusted because deployed systems are mostly using dedicated resources and are therefore considered secure and reliable.

The recognition of the need to adopt mobile broadband lead the public safety community to request new capabilities to be developed through 3GPP standardisation. This brought new potential capabilities with the aim to bring into PPDR the communication features we witness today in beyond-2G systems. These capabilities are quite different to those used by consumer users of mobile.

3GPP standards are evolving well in support of PPDR. However, this new technical capability is only useful if the economics of their deployment and use support a sustainable PPDR communication capability. Irrespective of the mobile technology adopted, 4G, 5G or the next generations:

- PPDR Users, in two separate levels of the value chains have unique needs with the same goal:
  - Ministries of Interior and their agencies responsible for public safety mobile communication must be satisfied that the services delivered for use by responders will be available and fit for purpose,
  - Responders that use the technology must find benefit through overall capability improvement, and not be hindered by the new technology.
- Commercial Mobile operators and equipment vendors must recognise the importance of the societal needs of public safety,
- Policy makers should carefully address the balance of societal benefits and economic regulation of telecommunications sector.

The new standardised capabilities useful for PPDR were initially focused towards 4G (Rel-13, 14) with further enhancements brought into 5G (Rel-15, 16, +). Early adopters of broadband for public safety primarily consider the 4G perspective which is determined by the commercial mobile networks that typically use technology based on older releases where technology components are mature. This is crucial for the stability of live systems. We therefore need to understand the incentives and timeframes associated with the adoption of 5G for consumers, so as to anticipate when services will become available for PPDR to consider adoption.

This paper will introduce proposed work that will assess the timelines to PPDR adoption of 5G, the technical benefits of 5G for PPDR and how to evaluate that. We consider a crucial importance to validation of the business case, policy and associated Ethical Legal and Societal (ELSI) issues. KPIs will extend way beyond the technical view on 5G, to include non-functional criteria in the view of PPDR users including ministries and their agencies responsible for PPDR communication and, of course, the responders that use these capabilities to protect and save lives.

As other vertical sectors (Vehicles, Healthcare, etc) are also present and using network resources, the 5th Generation of Telecommunications Networks (5G) aims to provide co-existence capabilities. PPDR users are moving from a position where security and resilience are guaranteed by isolated mobile networks and resources. 5G offers shared resources with other vertices and so PPDR users are faced with this new sharing paradigm where security and resilience is offered with a virtualised separation rather than a physical isolation. This poses a difficult change for PPDR users to accept. Early test, validation and evaluation with 5G is crucial to gain such acceptance. The economic case must assure sustainable provision and use of 5G services for PPDR, which may require new policy to support our public safety users. This is crucial where PPDR users have a huge burden of societal responsibility, require highly secure and reliable communications, yet our 3.5M first responders

 Date of Publication 14th December 2018

represent only 0.75% of mobile users in Europe (465M) today.

The remainder of this paper is structured as follows. Section II provides insight on the path towards 5G, followed by a definition of its benefits in 5G in Section III. Section IV introduces the main PPDR requirements for broadband communication, along with the identification of the necessary steps for PPDR and 5G integration in Section V. Finally, the paper concludes in Section VI.

II. Timeline and Maturity towards 5G

PPDR has been commonly deployed using Private Mobile Radio (PMR) networks, in order to provide insurances that would otherwise be impractical on public networks. ETSI TC TETRA was the technical committee responsible for the standardization of TETRA (a 2G equivalent). Once standardized, TC TETRA proceeded to standardize its wide-band version TETRA Enhanced Data Services (TEDS), which provided a wideband 3G equivalent. TETRA standards were first released in 1995, and TEDS first released in 2005. The limited economy of scale and governmental led (in most cases) nature of TETRA deployment lead to long deployment times. TEDS was deployed in only a limited number of cases, primarily due to the large investments required. As TEDS standardization became complete, TC TETRA WG4 began consideration on how to prepare for the future broadband capability exchanges. Besides the parallel investment required, the PMR-dedicated initiatives were technically less feature-enabled in regard to the public networks' progress. Two options were discussed: 1) to widen the bandwidth of TEDS to allow for a broadband capability, or 2) to leverage the rapidly evolving 3GPP standards. In that sense, PMR operators and involved organizations targeted broadband capabilities for PPDR by leveraging 4G Long Term Evolution (LTE) networks. This is largely due to the experiences related to the lack of uptake of TEDS and the high costs to governments requiring a very specific solution, with a limited marketplace. This allowed traditional PMR deployments, such as Tetra, Tetrapol and P25, to evolve from group-based communications. Nonetheless, public networks were specified targeting consumer markets, thus missing out on important PPDR requirements such as service guarantees, availability and capacity (which are fundamentally tested upon in crisis situations). In this sense, there was a unanimous need for specific research and standardization activities. Discussions of Requirements began in Working Group SA1 in 2012. 3GPP led the formation of Working Group SA6 in 2014 with the primary goal to standardize the technical details of Mission Critical Services. SA6 met for the first time in January 2015. The timeline for the 3GPP handling of PPDR aspects took the following form:

- Release-13 (completed March 2016) is the first release including Mission Critical Push to Talk (MC-PTT),
- Release-14 (completed June 2017) further enhances MC-PTT and includes new MC-Data and MC-Video services,
- Release-15 (completed Sept 2018) brings further enhancements,
- Release 16 (due December 2019) brings consideration of other vertical sectors requiring mission critical capabilities.

MC-PTT was originally driven by key projects in UK, US and South Korea. MC-Data and MC-Video requirements were heavenly driven by these originating countries plus other European Countries (France and The Netherlands), as they also prepare for a transition to broadband services in their country. This activity demonstrates a different approach in 3GPP standards with requirements being pulled directly from governments for public safety and from other specific vertical sectors. SA1 and SA6 currently consider new requirements from the automotive and rail market sectors, further building upon these new mission critical standards. The number of Market Representation Partners (MRP) of 3GPP is increasing as a result.

ETSI PlugTests have been run twice by ETSI in June 2017 and June 2018. Conformance specifications are now available for MC-PTT Release-13. Global Certification Forum (GCF) recently announced the offer of a service to carry out conformance testing.

The widespread direction to share 3GPP standards and share resultant services with existing commercial mobile operators are driven by 2 key decisions. Decisions at WRC'15 and a communication by the European Commission have led to a situation where it is highly unlikely that spectrum can be harmonized across Europe for dedicated use by public safety. This therefore places a significant requirement to share communication resources with existing infrastructures already providing coverage.

Figure 1 gives an estimation of timeframes of relevant standardisation and known pre-commercial activities already taking place. This is based on the timelines of several different activities:

- 3GPP 5G standardisation of Rel.15/16
- News of early 5G pre-commercial testbed deployments
- The timeline of pre-commercial BroadWay that aims to achieve pan-European broadband for PPDR.
- BroadNet represents the pan-European procurement of PPDR mobile broadband capabilities developed during BroadWay (www.broadway-info.eu).
- News of PPDR adoption of mobile broadband in different EU countries, considering:
    - early non-mission critical MVNO provision of 4G
    - early adopters of release-13 Mission Critical Push to Talk (MC-PTT)
    - Expectation of the adoption of full MC services as MNOs upgrade
    - The majority of European PPDR using 5G in the 2028+ timeframe

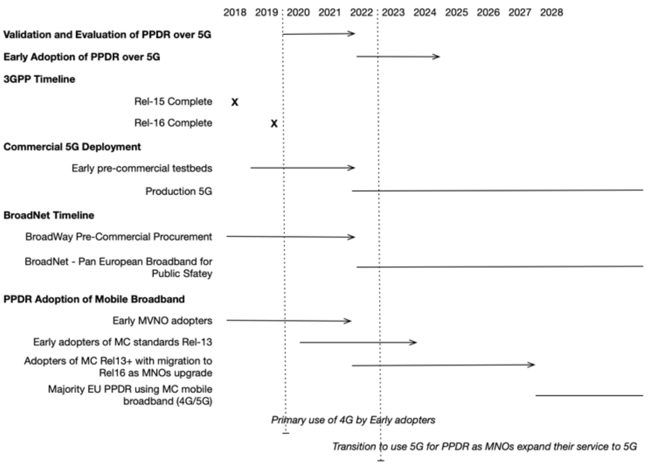

Figure 1 – Timeline of related standardisation and known pre-commercial activities

III. Benefits of 5G

The expected benefits of 5G for PPDR fall into three main axes, namely performance, density and service guarantee/availability. PPDR communications need reliability, but may also find new applications to exploit data rates that 5G provides (e.g. augmented reality). The higher data rates come with higher fading dynamics [1] and also [2]. Dual Connectivity allows a UE to concurrently connect to 2 radio nodes [3], initially EN-DC (concurrent 4G and 5G connections), but eventually this will be extended to multi-connectivity (2 or more) with only 5G radio connections. This dual connectivity has the potential to dramatically increase reliability, especially when high capacity channels are being used. Currently this can be facilitated by rudimentary duplication of packets across the 2 connections [4]. Even with simple duplication there are significant reliability gains, though not so efficient use of resources [5]. In 5G this multi-connectivity functionality will be enhanced and exploited to provide reliable PPDR services at the transport layer allowing PPDR communications to exploit the high 5G data rates and maintain a highly reliable service. PPDR information will be intelligently channeled over the appropriate connections to provide the required services with the necessary reliability. Reliability can be further improved by using multiple connections to multiple providers [6]. Using multiple providers will enable much higher bandwidths for the UE for higher quality video transmission and sustained service while improving reliability to the levels demanded by PPDR applications.

A. 5G Network capabilities for PPDR

PPDR may also be able to leverage key 5G enablers, mechanisms and operations allowing the dynamic, elastic and performing operation of Security Communications in heterogeneous, multi-domain, and multi-tenant environments featuring different infrastructure operators, verticals, users and services in use.

Further PPDR-dedicated enhancements can be developed, capitalizing on the enablers providing by the 5G architecture, and its experimental evaluation over trial platforms will elevate key network and information services technologies that are integral part of the 5G services and enabled therein. These include: New Radio (NR), virtualization, slicing orchestration and federation, Mobile Edge Computing (MEC), Critical Communication extension and multi-slicing.

The deployed solution will integrate advanced orchestration capabilities to allow the quick dynamic instantiation of the necessary network slices, granting involved responders and entities (whether local, remote, automated or human) to communicate with performance and isolation from the remainder of information traffic traversing existing networking infrastructure in the vicinity, and supporting relevant network function relocations. We must test and validate frameworks and configurations for multi-slice bonding, both on the network side and on the UE side, to drive PPDR solutions with a lower-cost (CAPEX, OPEX) and higher performance. A key aspect of PPDR-based enhancements to 5G is that they have the capability to enhance the network slicing concept to go beyond the isolation of communications in common infrastructure resources, and rather define procedures allowing such slices to realize what we dub as the “five D’s”:

i) *Dynamically scale*: provision “an on-demand breathing network” using an increase/decrease capacity, range and other parameters to continuously optimize network resources, both for communication and for data collection, in response to (and in the future also in prediction of) the evolving emergency situation and existing regular communications at that location; This may be physically possible via the aggregation of existing network capacity from pre-existing network operators, via the addition and creation of ephemeral extensions through deployable base stations, or via the inclusion of alternative communication options (e.g., satcom). Nevertheless, this quick setup and dynamic management goes beyond what is done today and represents a challenge on its own.

ii) *Dynamically move*: allow the created emergency slices to “follow” responders, as their communication devices move through the theatre of operations, and change their attachment between different available access network technologies (e.g., maintaining communications with fast vehicles that arrive, stay or leave the area, such as aerial fire-fighting units that need to leave the fire to refill their water tanks), thus maintaining response with full participation of all communications during the multiple procedures that they take;

iii) *Dynamically interoperate*: to maximize availability and bandwidth, while reducing CAPEX and OPEX in maintaining dedicated or ad-hoc PPDR networks, allowing network services orchestration procedures to be realized over different domains, such as leveraging the infrastructure of different mobile network operators, retaining 4G LTE access or using different access technologies such as satellites (e.g., allowing established resources to seamlessly handover between communication providers, keeping state such as caller identifiers, paging locations, and other elements, in a transparent way to involved parties).

iv) *Dynamically secure adjustments*: allowing the critical PPDR communications, as well as all the other traffic, to remain secured and isolated regardless of where the actual deployment of the slice components is done (different domains, different technologies), the different access network infrastructures in use, as well as the services, types of users and verticals involved, as well as minimizing the

Date of Publication 14th December 2018

impact on user privacy. It is important to address such cases, very common during real PPDR operations, where there is the need to make possible the - long-term or sporadic - collaboration between different entities (agencies, or cross-border organizations).

v) *Dynamically costing*: using the said technologies, a dynamic cost may be structured so that higher cost is only incurred when the usage increases, due to the specific emergencies. Also, cost-performance optimization may be achieved by these technologies, e.g., by generating and using lower cost slices for some services or users, perhaps with higher density, and having higher performing slices only for selected PPDR services as needed. Multi-slice approach can combine "sub-slices" to create that higher performing higher cost slice for the enabled/permitted devices.

The 5G network PPDR-focused slices may deliver important basic service guarantees to PPDR users:

Always-on information: Enhancements for PPDR over 5G will provide the capability for responders to always be connected to information sources on the theatre of operations, by allowing different network technologies and operators to be used in a transparent, seamless and cooperative way. Responders will continuously have access to information, even as they move in, out, or between situational areas. This will end the need for spending precious moments catching up and debriefing operatives, as they switch context, no longer clogging communications with repetitive reports, as every intervenient will have complete constant situational awareness;

Trans-location access: Missions often have a geographical scope that can dynamically scale both in and out, having the potential to fall into the domain of different national and international borders. From a technological perspective, these are currently seen as hindering smooth communications provisioning. Project BroadWay seeks to solve this problem from a whole EU system of national systems perspective, solving much wider problems in which 5G may contribute. PPDR responders may operate from one country and go to aid another one. It is required that they may start their work immediately without interruption, or barriers. Roaming for PPDR, either in their specific slices or in the standard/regular commercially available slices, is an example;

Secured and quality information exchanges: 5G enhanced communication mechanisms will ensure that information, whether being voice, video or data, will be handled securely and reliably, even while sharing different communication channels from existing infrastructure (i.e., mobile networks);

Integrated information processing and provisioning: Data on networking and information services will continuously be collected and processed by various agents, and processed using state of the art algorithms, aiming for continuous and dynamic optimization of the communications infrastructure to the emergency at hand. MEC, Fog Computing and Cloud Computing will be assessed for several PPDR applications, such as video distribution;

Multi-slice and multi-link bonding: using multiple access options, such as multiple slices, multiple networks, multiple operators, and multiple Radio Access Technologies (RAT) can deliver the reliability, availability, high bandwidth and high density needed in many PPDR use cases. The principle of being able to exploit "every bit available" for PPDR on demand and as needed, is aligned with the need to best serve the PPDR needs, locations and circumstances. Simultaneous use of multiple slices by the same UE, combining and splitting slices at the cellular network level, bonding and using multiple access technologies or operators such as 5G with LTE, or Satellite communications, all provide such benefits, at various cost-performance levels;

B. 5G Network-based applications for PPDR

5G performance and capabilities are expected to be supportive for critical services for PPDR users, among which we emphasize:

- Real time Multimedia (voice, data, video): real time MCS (MCPTT, MCData, MCVideo) will be provided to those first responders on site and in control rooms, to allow efficient coordination and communication, including for demanding and bandwidth hungry applications (e.g. broadcast of real time video, information flows coming from various sensors, augmented reality), with a high Quality of Experience (QoE) for the end users, enabled by 5G high performance (e.g. high bandwidth, low latency, broadcast). As an example, broadband video services are highly expected by PPDR organizations.
- Support for massive number of devices: one of the key requirements for PPDR is the delivery of simultaneous (several tens) real time and non-real time flows (e.g. mixed traffic profiles of voice plus video real time plus data) to large groups of users (several hundreds, up to a couple of thousands) within a small area (potentially within a single cell).

C. Business KPIs

Innovation potential of 5G for PPDR can be identified as non-functional a business level in the following categories:

- Capacity
  - Does the increased capacity of 5G provide enough communication resource for PPDR?
  - Does it provide enough capacity to also easily co-exist with other verticals and applications?
- Availability
  - Do the foreseen 5G deployments provide coverage and performance in all areas? including, for example, underground, rural, urban, air, near shore sea/lakes, road, etc.
  - Does 5G allow for better coverage though integration of alternative bearers, e.g. 4G and satellite?
  - Will 5G be dynamic enough to adapt and transit from daily-regular PPDR scenarios to fast changing disaster situations?
  - Will 5G enable multinational cooperation and cross border response capabilities
- Security
  - Are 5G new capabilities more or less secure?

- What measures are required to give confidence, for example, that police operations will not be influenced by malicious cyber activities.
- Does the supply chain maintain high assurances on software quality and security?

- Standardised technologies
  - Are the technologies of 5G fully standardised? PPDR are witnessing a 15-20 year vendor lock situation retaining only 2G communication capability. This is hindering capability development and innovation for PPDR. This must never happen again. Responders must have the same, if not better, technology than criminals, and rich information capabilities to help find those lost people during a forest fire or respond to rescue people after an earthquake.

IV. PPDR Needs for Broadband Communication

The use case scenarios for advanced large-scale and realistic in-the-field trials, and the close collaboration and co-creation together with relevant stakeholders and expert users will allow 5G technologies not only to progress on the development of critical PPDR building blocks and applications per se, but also progress on and achieve additional advancements in smart ways of configuring, using and managing such PPDR solutions, as well as improving the way PPDR applications and terminals are adapted and used by the first responders. These advancements will reflect the needs and requirements in coordination and alignment across the MNOs, the PPDR control centres, and the PPDR in-the-field first responders. These capabilities will take into account planning and relevant operational procedures as well as highly dynamically changing contexts and environments. While the users of advanced future PPDR communication solutions and services will gain potential access to a whole new range of devices, services and features, there will be a need to communicate in a smart and user-friendly way with service levels that are available at a given place and time. This is important to set the level of expectations and realistic use of these devices, services and features in the face of PPDR stakeholders.

A. *Regulatory Considerations*

Future adoption of 5G will be subject to many other non-technical aspects, particularly considering the Legal and regulatory framework that will govern adoption on PPDR service over 5G. The following gives a non-exhaustive list of avenues that should be explored:

- Spectrum policy Internationally and nationally,
- BEREC oversight and national regulation,
- Telecoms Framework package,
- European 5G Action plan,
- European and National Cyber policy (ENISA) – NIS Directive,
- National Broadband plans, incorporating 5G – DG Connect COCOM,
- Net Neutrality,
- General Data Protection Regulation (GDPR),
- eIDAS, eTrust, ePrivacy, etc.,
- International and national procurement laws.

It is thus important to identify and assess the level of Legal, Policy, Ethical and Societal considerations within PPDR integration into 5G and provide the tools and guidelines for their effective management. Foreseen activities in this approach could examine all methods, tools, technologies and processes applied by 5G (and PPDR 5G enhancements) and the scenarios that may infringe or jeopardize participants' rights, legal requirements and implications of training and potential undesired ethical and societal impacts. Attention must be paid to the national and cross-European aspects. Additionally, a structured continuous approach to identify and appraise the key criteria and concerns for societal acceptance and ethical matters should be taken.

V. Steps to be Taken to Evaluate and Adopt 5G for PPDR

A. *Networking Aspects*

The provisioning of PPDR communications exposes the networking fabric to a challenging set of objectives and requirements which demand the availability of control and operation mechanisms able to ensure such provisioning. This is particularly critical when considering the joint support of regular communications and other transversal issues such as dynamic coverage required due to emergency situations, amongst other challenges. As 5G-enabled technologies are being standardized and evolved to encompass such disparate conditions and possibilities, while providing greater flexibility and dynamism in network deployment and operation, it is important to assess, validate and evolve this underlying networking fabric, while handling PPDR situations. Despite ongoing research and standardization efforts, PPDR systems and applications must contribute to the design of future 5G end-to-end systems by bringing real use cases, and trialling them with available technology, outputting results to society, stakeholders policy and standards definition organisations. From the technological and solutions perspective, or the "supply" perspective, it is important for PPDR focused activities (i.e., applications, services, interfaces, amongst others) to leverage on the knowledge and the exploitable results developed in ongoing 5G developments, both at the Radio Access Network (RAN) and core network level (e.g., Network Function Virtualization (NFV), Software Defined Networking (SDN) network slicing, and others), existing trial sites dedicated to 5G along with extensions and enhancements, and the deployment of the industrial and Small and Medium Enterprises (SME) 5G products (e.g., Rel.15 gNB nodes and future Rel.16 compliant products). On the "demand" side, or end user's needs, 5G needs to address PPDR operations in respect to critical communication scenarios (which, as of today, are not yet available in the previously mentioned platforms), while addressing the necessary innovation developments as well to manage and operate the network system when human lives are at stake. In this way, for the various stakeholders involved (ranging from operators, to manufacturers and service providers) to reach the PPDR market, they require the development of mechanisms capable of handling life-threatening operations of ICT solutions.

B. PPDR Validation Challenges

The challenge to validate 5G solutions for PPDR is a complex one. Many ICT projects and their partners are safe in the comfort of their technical bubble. When we reach to the higher TRL's, moving beyond the lab-based testing against technical KPIs and engaging more with business stakeholders, we encounter different ways of working and even different working language. The language of the technical engineer is significantly different to that of a real PPDR responder. Responders care only that the technology works to support their operations to protect the public and save lives. If it doesn't, then the technology will be rejected. Technology developers of 5G are several steps away from the real PPDR responder in the value chain. It's important to understand who the appropriate stakeholder should be to represent the provision of communication services to the PPDR responder. We see here the onward provision of:

i) mobile technologies from developers, to,

ii) commercial mobile operators, to,

iii) nationally mandated organisations responsible to deliver communication services to,

iv) PPDR responders, who require enhanced communication capability.

When considering the provision of PPDR communication services, we encounter further discipline differences. For example, from a technology perspective we could be confident that 5G-PPP KPI's for PPDR are sufficient. From the perspective of communication provision to a PPDR responder, the presentation of this is highly unlikely to be convincing. PPDR responders will judge the utility of a technology in a more specific sense. Even if their shiny new gigabit/second device has impressive capability in terms of capacity and latency written on the box, if it doesn't provide the correct information, accurately, on-time and when it's needed, a life may be lost. This issue can be addressed considering the following two mechanisms:

A) Co-creation, Technical validation and PPDR Evaluation

Co-creation - technology should be deployed on the testbeds taking into account new knowledge from working closely with PPDR stakeholder representing complimentary and different views from across Europe. There will be many technical challenges to integrate the different facets of 5G technical capabilities. However, to be able to assess the utility of 5G for PPDR, 2 different assessments must be made:

- Technical Validation– The technical team evaluating the technical performance in PPDR use cases
- PPDR Evaluation– National PPDR operators assessing the utility of the technology for PPDR and the business case for adoption

The process of Validation and Evaluation requires a co-creation process combining both technology developers and PPDR stakeholders. A methodology that is developed specifically to allow PPDR and crisis management actors to trial and assess new technology should be adopted.

B) The European mobile sharing eco-system supporting PPDR

Mission Critical capabilities are new. Provision of services for PPDR by commercial mobile operators is new. This is a complex and difficult to understand business model. In conversation with mobile operator EE who provide service for the new Emergency Service Network (ESN) to the UK Home Office we find that their motivation is founded on the basis that hardening of the EE mobile network, provision of extra coverage and security can only help build trust with consumer users. This can only provide a competitive advantage in provision of consumer mobile services, and also opens other 'business critical' classes of mobile service provision.

5G services are new, not just from a capacity and latency perspective, but from new capabilities for offering shared infrastructure. Concepts like slicing are only understood by PPDR stakeholders in terms of papers and promotional materials. National PPDR operators currently have no operational experience with this new sharing model. Sharing of infrastructure is a new consideration for PPDR operators. Many studies have been carried out that consider the cost/benefits of sharing. Analysis Mason (July 2018) [7] concludes that the full life cost of sharing PPDR services over commercial mobile networks is roughly 30-40% of that expected from providing dedicated networks. PPDR operators are familiar with dedicated narrowband systems (TETRA/TETRAPOL) and are considering carefully the change from using dedicated and harmonised spectrum, to provision of shared broadband services. Whilst the cost savings are clear, this is a significant culture change. Dedicated networks are perceived to be more secure, with reliability under direct control. Sharing imposes a dependence on the services of others, shifting responsibility of elements of security and reliability to other parties:

- Business case – The commercial motivations of 5G commercial mobile operators must support provision of PPDR services. PPDR responders represent on 0.75% of mobile user in Europe, therefore commercial motivation may be limited, considering addition investments required to provide PPDR grade MCS.
- Policy and Regulation– European mobile regulations focus specifically on the mobile economy that represents 3.3% of European GDP. Policy and regulation will be required to safeguard this small number of highly critical users.
- Standards – A significant progress has already been made to support MCS for PPDR. However, the maturity of solutions fulfilling these standards is still low and there may be new and more efficient ways to provide 5G MC services.

VI. CONCLUSION

In this paper we see 5G as an opportunity to satisfy the under-served communication needs of the European PPDR community and its multiple vertical entities, while gaining capability advantage using the most advanced communications solutions for enabling their daily and emergency Operations. We aim to raise the awareness for the need to explore the existing (and upcoming) commercial and research experimental environments to provide a PPDR-centred assessment of 5G technology capabilities from the point of view. Reflection back of assessments should influence 5G policy and direction for standardisation. The overall goal is to prepare the evolution path of these PPDR stakeholders, national and international governments and regulators to explore 5G technology. It is important to seriously assess and explore the 5G technology capabilities now, developing knowledge, technology and experiences that will prevent these PPDR critical operations falling back to only being able to use voice or short amounts of telemetry data (as has been happening in the previous generations). This will judiciously allow for the smooth integration of these novel capabilities for PPDR.

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