Is it time for a 999-like (or 112/911) system for critical information services?

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***Abstract*— The nature of information gathering and dissemination has changed dramatically over the past 20 years as traditional media sources are increasingly being replaced by a cacaphony of social media channels. Despite this, society still expects to disseminate its critical information via traditional news sources. Public Warning Systems (PWS) exist, but concerns about spamming users with irrelevant warnings mean that mostly only life threatening emergency warnings are delivered via PWS. We argue that it is time for society to upgrade its infrastructure for critical information services (CIS) and that a smartphone app system can provide a standardised, less-intrusive user interface to deliver CIS, especially if the traffic for the app is prioritised during congestion periods. Accordingly, we make three contributions in this paper. Firstly, using network parameters from our longitudinal measurements of network performance in Central London (an area of high user traffic), we show, with simulations, that reserving some bandwidth exclusively for CIS could assure QoS for CIS without significant degradation for other services. Secondly, we provide a conceptual design of a 999 CIS app, which can mimic the current 999 voice system and can be built using 3GPP defined systems. Thirdly, we identify the stakeholder relationships with industry partners and policymakers that can help to deliver a CIS system that is fit for purpose for an increasingly smartphone-based society.**

Keywords - net neutrality; traffic prioritisation; priority lanes; 112; 911; 999; emergency; critical; CLASP

I. Introduction

Throughout history, every society has sought ways to communicate important and critical information to citizens. For context, official speeches by Presidents and Heads of State, a notable example of such important information, is often prioritised for wide dissemination in most countries. In the UK, the traditional Christmas message from Queen Elizabeth II (the Head of State) is typically the most watched TV programme on Christmas Day. In 1957, 15.1 million viewers tuned in, nearly 30% of the total UK population [1]. In 2018, the Queen's message was again the most watched TV programme on Christmas Day. However, this time, only 6.4 million viewers tuned in, about 10% of the UK population [2].

The declining viewership of the Queen's Christmas Day message on TV is a victim of a trend that has eviscerated the traditional media landscape. Local TV and radio stations are struggling and newspapers are, seemingly, in terminal decline. Instead, these traditional news sources are being replaced by a cacophony of social media channels (e.g. Facebook, Twitter), streaming services (e.g. Netflix, YouTube) and citizen-journalists (e.g. blogs).

In this digital landscape, how can a society convey its most important information - its Critical Information Services (CIS) - to a citizenry that is increasingly disinterested in traditional information sources or where the integrity of the news providers is questionable? How should society evolve the distribution medium for critical/important information that is currently prioritised on TV, radio and newspaper (e.g. warning/emergency/safety information, traffic/weather news, governmental information)? Mobile phones, either via SMS or through Public Warning Systems (PWS) (e.g. Cell Broadcast) [1] are already well established for information dissemination. Recently, smartphones have emerged as an important channel for emergency and critical information because of their ubiquity and ability to support multimedia messages, and because they can be used for CIS at a lower threshold than that permissible for PWS - concerns about spamming users with irrelevant warnings means that the threshold to use PWS is set very high [2], [3]. For example, several provinces in Canada have launched the Alertable app to provide emergency weather information [3]. [4] provides a general survey of smartphone systems for emergency management.

What is missing though, is a coordinated (whether at global, national or local levels) to validate and standardise a reliable smartphone system for CIS, and then educate users on what to expect (similar to how users are trained on what to expect when they dial 999/911/112 numbers). This is the basis of our work - building on our experience in academia and industry to find possible solutions for this problem.

As highlighted in [5], a crucial observation about most cellular-internet-based systems is that the susceptibility to network conditions is democratic. In other words, an app-based CIS service is affected in the same way as an online shopping or infotainment service. This democratic outcome is not surprising given expectations about net neutrality. All services are served by the same 'best effort' internet connection and society expects the overall performance to get better with improvements in technology and addition of more network capacity. Our ongoing longitudinal studies on network performance confirm overall improvements in network

[1] https://www.bbc.co.uk/historyofthebbc/christmasday

[2] https://www.bbc.co.uk/news/entertainment-arts-46685728

[3] https://alertable.ca/#/

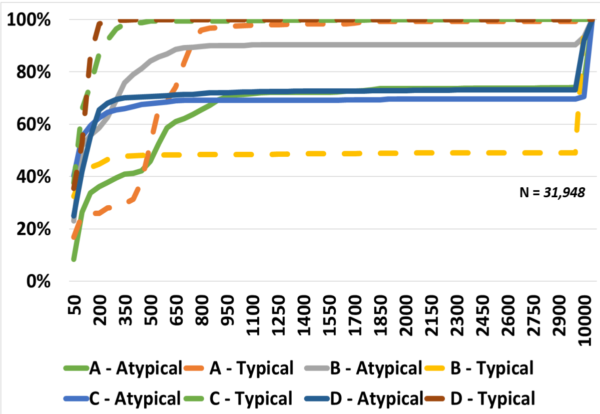

Fig. 1: Median RTT for 14 websites showing that performance existing network capacity is insufficient to assure QoE for critical information services during atypical scenarios. Measurements are for Atypical (31/12/2017 - 01/01/2018) vs Typical (14/01/2018 - 15/01/2018) scenario on Operators A - D networks. The measurements are from a longitudinal annual study to understand network performance during New Year fireworks celebrations in Central London.

quality, but note significant occasional poor performance that could continue to undermine the reliability of CIS in the 5G era. For example, as Figure 1 shows, measurements of round-trip-time (RTT) for selected UK websites on the four UK cellular networks over a 24-hour period in 2017/18 (from 12:00 noon on 31 December to 12:00 noon on 1 January) vs same time 2-weeks later (14 January to 15 January) show that available network capacity is not sufficient to guarantee QoE to CIS systems during atypical scenarios. The median readings from the CDF show that over 35% of RTT measurements for atypical scenario were above 1000 milliseconds. Measurements were taken from the same location in Central London, near where over 100,000 people gather for the New Year eve fireworks celebrations.

Since the UK set up the 999 voice system as the first emergency services number in the world in June 1937 [4], most countries have set up similar systems to support public safety initiatives (e.g. 112/911). Building on the global acceptance of the 112/911/999 system, this paper explores the possibility of delivering CIS via a dedicated/prioritised 999 app system, focusing on periods of network congestion. Accordingly, we make three contributions in this paper. Firstly, as explored in Section II, we survey the existing 3GPP systems that can be used for traffic prioritisation and show that reserving and using dedicated bandwidth, especially during congestion periods, can provide quality assurance for CIS without significantly impacting other services. Secondly, in Section III, we conceptualise and propose a 999 app CIS solution which can provide the practical vehicle to deliver CIS in the smartphone era. Thirdly, in Section IV, we acknowledge that our work is the first part in a four-part task and identify efforts to engage with the telecoms industry and policymakers to deliver on the system. Section V provides some concluding remarks and points to the further work that we will be seeking to do.

[4]http://home.bt.com/tech-gadgets/what-happens-when-you-call-999-the-secrets-of-the-emergency-services-number-11364191315763

II. Considerations for CIS

A. Quality assurance for CIS

Prioritisation, together with adding new capacity, is the industry's default means of providing quality assurances to some services during congestion periods. In practice, prioritisation helps operators to better manage their networks and improve capacity utilisation by pricing different types of traffic differently. This has been the basis for numerous tariff plans for peak/off peak and the current research interest into Smart Data Pricing (SDP) [6] with several trials [7]. Evidence of mass market adoption of SDP is scarce though [8]. Another example is Zero rating - the practice of giving customers free access to selected Internet content - which is fairly established as a commercial prioritisation proposition [6].

Prioritisation is also used to assure quality for statutory services - e.g for VoLTE over a data connection in 4G networks. The engineering community has anticipated the need for prioritisation of different traffic types. For example, the Resource Reservation Protocol (RSVP) [9] and the QoS Class Identifier (QCI) [10] were all designed to allow some form of prioritisation of network traffic. Prioritisation for 5G era systems is mostly focused on how to use 5G QoS Identifier (5QI) and Network Slicing to deliver bespoke network capabilities to different use cases.

Generally however, regulators and campaigners who are committed to maintaining the principle of Net Neutrality object to prioritisation. As a result, much of the hesitancy to use prioritisation can be linked to caution about violating the principle of Net Neutrality, a techno-social concept that is shaping debate about Internet governance.

Based on these observations, we synthesize five generic mechanisms for managing the flow of traffic to provide quality assurance for CIS during congestion periods:

1) Prioritise some traffic: CIS can be expressly and always prioritised in the network so as to assure their availability and reachability. This can be done by reserving special lanes for CIS or to treat the CIS data packets as special packets.
2) Delay some traffic: Traffic without an appropriate priority label can be delayed during congestion periods to improve the availability and reachability of CIS.
3) Impose an average speed/throughput for all or some traffic: Operators may be able to truncate speeds for all services during congestion periods in order to improve throughput for some or all services. This is akin to the average speeds imposed on motorways during busy periods to increase the capacity of the road network.
4) Pre-fetch some traffic during periods of low demand: Information that is deemed to be critical can be pre-

fetched and cached at the core or radio network, or potentially pushed to the user device for local caching.

5) Changing how some traffic is billed: For customers still using metered Internet services, the cost of using non-critical services during periods of congestion can be varied in order to discourage their use and assure more resources for critical services.

In this paper, we focus on (1) and explore how prioritisation can help to assure the QoE for the CIS service.

B. Engineering for CIS - 3GPP options

Within the 3GPP specification system for cellular networks, there are four technical implementation options for assuring quality for CIS - three options will provide 'special lanes' for CIS traffic and one option will treat CIS traffic as 'special packets'. These are described below and Table I provides a comparative analysis of the four mechanisms.

1) Public Warning Systems: The Public Warning Systems (PWS) requirements from 3GPP Release 8 onwards provides a special lane to distribute text-based PWS messages. In Stage 1, Release 16, 3GPP is considering to enhance PWS to include non-mobile-phones and also to make it applicable for non traditional scenarios for vehicles, machines etc [11]. These enhancements will enable the plethora of Internet of Things (IoT) devices - cars, smart meters, robots, wearables - to be able to receive PWS messages in emergency and critical scenarios.
2) Service Accessibility Mechanisms: The service accessibility mechanisms, summarised in 3GPP Release 14 [12], describe a set of access procedures which determine whether a user can gain access to special lanes or not when enforced. These were also defined from Release 8 and includes several mechanisms that can be used to regulate network access for devices or applications [12]. Two particular mechanisms that may be applicable for emergency and critical data services are the Access Class Baring (ACB) to determine network access for the device and the Application specific Congestion control for Data Communications (ACDC) to determine network access for specific applications on a device. ACDC is an example of 999 priority lane for critical data services as explored in [13].
3) Network Slicing: 3GPP Release 15 introduced the concept of a network slice (a form of special lane) that can be dedicated to emergency and critical services [14]. Network Slicing has been suggested as the optimal way to manage the network to deliver the required capabilities for each of the services from the same underlying network infrastructure [15], [16].
4) 5G QoS Identifier (5QI): 3GPP Release 15 also introduced a QoS model that provides for guaranteed bit rate (GBR) and non-GBR traffic flows [14]. A key component of this new model is the 5G QoS Identifier (5QI) which will replace the current LTE-based QoS Class Identifier (QCI) [17], [18]. This should be the default mechanism to manage prioritisation for traffic flows for emergency and critical data services. 5QI will treat CIS traffic as special packets, is implemented by the Policy and Charging Rules Function (PCRF) in the core network and is designed to provide for guaranteed bit rate (GBR) and non-GBR traffic flows.

C. Simulating prioritisation via special lanes for CIS

A common concern about prioritisation, whether for special lanes or special packets, is that in a zero sum game for network resources, reserving any bandwidth for a CIS system will lead to a deterioration for other services. This is based on the finite capacity of a cellular network as determined by the Shannon bound. [19] provides insights on how this consideration is applied in practical LTE network design and deployment. This can be used to determine overall number of subscribers that can be supported in a given cell and the average downlink throughput per subscriber.

In general, the number of subscribers g supported in a cell site [19] is given by

$$g = c.f/((1+d).e)$$

where:

- a = downlink cell average capacity (assume 33Mbps/sector for LTE)
- b = designed downlink cell loading (typically 70%)
- c = a x b = designed downlink cell capacity in Mbps per sector
- d = peak to average ratio (typically 20%)
- e = average downlink bandwidth throughput per subscriber
- f = number of sectors in the cell site

Figures 2 and 3 show average simulations (for 10,000 iterations using different combinations of 'g' and 'e'. The number of cell site sectors 'f' is based on actual network measurements, as recorded by our devices, from our longitudinal study of network performance, for each of the four UK cellular operators as captured in Central London on both atypical day and typical day in January 2018. We also assume that Radio Resource Connection (RRC) limits number of concurrent users, based on uplink configuration, to 1000 [17].

The results show that there is a noticeable degradation in overall network quality when bandwidth is reserved for a CIS system. This is most pronounced as the reserved bandwidth is increased from 50 to 300kbps. Based on this, any bandwidth reservation for CIS should typically be restricted to 100kbps (sufficient for a voice message or whatsapp voice call) in an LTE system to minimize QoS deterioration for other services.

D. Implementation options for CIS

The PWS system is the only established, and most widely used CIS system as indicated in Table I. For example, it is implemented as EU-Alert in European Union countries,

TABLE I: Comparative analysis of 3GPP systems for CIS

	Key Features	Operational Readiness	Market Readiness
Public Warning Systems	Special Lane mechanism. Broadcast-only mass-messaging system. Pushed-to-the-customer. Unaffected by congestion	Fully developed for text and covered by existing regulations. Unsuitable for multimedia content and minimal signaling	Well understood. Spam avoidance leads to tight restriction of use in pushing messages
Service Accessibility Mechanisms	Special Lane mechanism. Access-control-based bi-directional communication system. Can be applied at device or application level. Enables prioritisation during congestion	Standards are already in place and covered by existing regulation. ACB already implemented. No evidence of ACDC implementation. Decision made at the device or app level, minimising signaling load	ACB is widely in use with minimal user complaints. ACDC should inherit market reputation
Network Slicing	Special Lane mechanism. Isolation-based bi-directional communication system. Creates virtual networks for each end-to-end slice. Enables prioritisation during congestion	Standards are in place but regulation is still subject to discussions on net neutrality. As signaling load will be high to create and manage separate logical networks, actual operational implementation still unclear	Customer appetite remains unproven
5G QoS Identifier	Special Packet mechanism. Class-of-service bi-directional communication system. Applies at the traffic flow level. Enables prioritisation during congestion	Standards are in place but regulation is still subject to discussions on net neutrality. Operational complexity may limit usage	History of QCI leads to doubt on actual usage

Alert Ready in Canada, Earthquake Early Warning in Japan and Wireless Emergency Alerts in the USA. The GSMA provides a summary of PWS systems, case studies of actual implementations and some consideration of the challenges [5]. As a pushed-to-the-customer, broadcast-based system, one of the biggest challenges is managing user perception that they are receiving too many alerts that do not necessarily apply to them. The GSMA summary notes that this is an existential concern for PWS systems (similar to concerns about SMS spamming [20]) and has led to stringent thresholds for messages that are delivered via PWS. An example of this ongoing concern can be seen in the US, where following a review during Hurricane Harvey in California, the FCC voted to compel participating PWS providers to deliver emergency alerts within a tight geographical boundary and to limit the messages to a 360-character maximum lenght [6]. The consequence of this concern is that PWS is recommended only for life and death emergency situations and all other potential uses are prohibited.

But there are many more information notices that are not for life and death emergency situations, but which ought to be pushed to users in a non-intrusive way and considered for prioritisation during network congestion. A cursory look through any local newspaper shows important, and sometimes mundane messages that every resident ought to see. These could be about refuse collection, local transport updates (e.g. road closures), or other sundry administrative issues. Accordingly, we conceptualise and propose a general CIS solution which can be used to manage both emergency alerts and other sundry CIS messages.

III. Conceptual Model of a 999 CIS system

Given the right technical solutions and a favourable policy framework, an app-based 999 CIS system would build on the architecture of existing 999 voice systems. Using the same architectural design (Figure 4 for the UK system), the 999 app will aggregate all relevant information and is given priority access in the network (see Figure 5). The app aggregates all the relevant CIS content into a single portal, and can also integrate PWS systems. It will involve a content aggregator, operating at the local level, who is able to integrate relevant local information sources.

Unlike current PWS systems, the 999 app could also include more multimedia content and with a lower threshold to accommodate both emergency alerts and a wider range of CIS messages. Current PWS systems can continue to be pushed-to-the-customer. But non-emergency CIS notices can be delivered to the app with no alert and the customer pulls the information whenever they open the app. Information delivery to the app can be via broadcast mechanism (similar to PWS/SMS) or they can be pulled via eXtensible Messaging and Presence Protocol (XMPP) or an Application Programming Interface (API).

In our design of the 999 app, we have used a traffic light system to highlight the criticality of the CIS message. Red signals are reserved for current PWS systems and missing person alerts which need to jump to the front of the screen so that they are visible to all users immediately. Amber signals are used for less critical news (e.g. road closures and government messages). These are only visible when the app is opened. Green signals are used for more mundane news (e.g. weather forecast, local news etc) and are recommended to help train users to rely on the 999 app as their source of trusted news and information. Our app also has three levels to ensure that information is either international, national or local/regional. International level is relevant for travellers who are able to receive travel warnings or consular support in foreign destinations. Operationally, our design considers three mechanisms to ensure that the 999 app can deliver CIS messages everywhere, and regardless of congestion.

1) Background updating: As it is originally specified to activate when a device is in 'idle' mode, ACDC will provide a mechanism to refresh the content of the app regularly during typical scenarios.
2) Priority during congestion: Using an enhanced ACDC

[5] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/Mobile-Network-Public-Warning-Systems-and-the-Rise-of-Cell-Broadcast.pdf

[6] https://www.recode.net/2018/1/8/16864564/fcc-pai-wireless-emergency-alerts-harvey-wildfire-reform

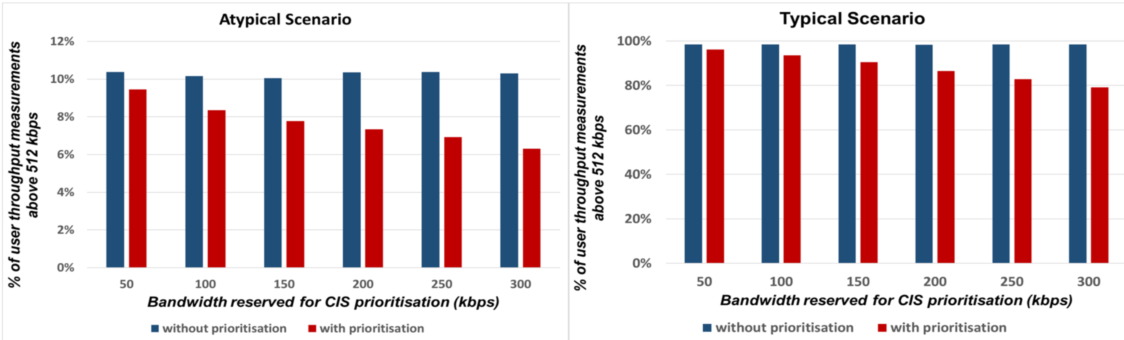

Fig. 2: Proportion of simulated user bandwidth above 512kbps based on actual measured network parameters over a 24 hour period for Atypical scenario (31/12/2017 - 01/01/2018) (left) vs Typical (14/01/2018 - 15/01/2018)(right) scenario. Network parameters are based on median measurements for the four UK cellular operators in Central London UK near the New Year fireworks celebrations

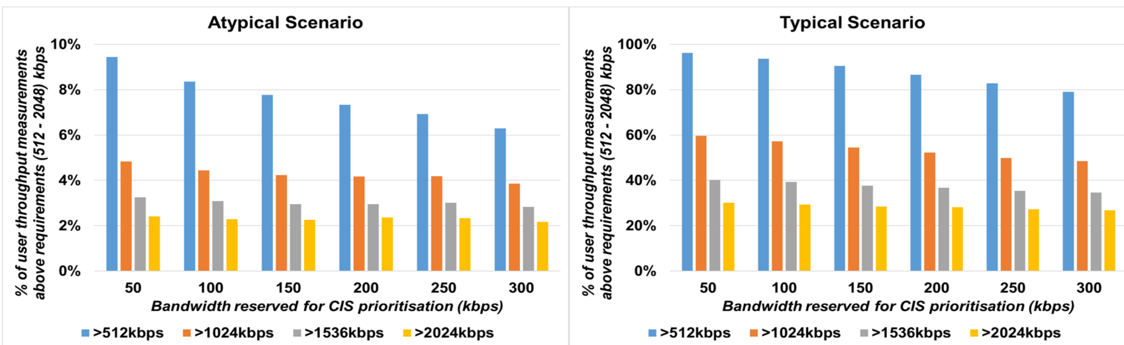

Fig. 3: Proportion of simulated user bandwidth above 512 - 2048kbps when bandwidth of 50 - 300kbps is reserved for CIS

which permits prioritisation for devices in 'connected mode' will ensure the app is given priority in the event of congestion.

3) International usage: Similar to SMS, the 999 CIS app would be included as part of 3GPP 'Data Off Exempt Service' package [21] to ensure that it is operational even if users have switched off data roaming.

IV. 999 CIS APP: FROM THEORY TO PRACTICE

While our proposed 999 CIS app is a novel contribution, we acknowledge that there has been several attempts to implement traffic prioritisation and these have failed to take off. For example, in our engagement with engineers managing live production networks, it is clear that application level access control for end user services is uncommon. This can be seen in the usage levels for QCI. Despite a choice of at least 15 QCI levels, most services on 4G networks use QCI Level 9 as default bearer; the only exception is Voice over LTE (VoLTE) which uses QCI Level 1. We are also unaware of any live production network using ACDC widely (perhaps because it was only finalised in 3GPP Release 13). Other earlier attempts to provide differentiated service classes - such as IntServ/RSVP [9] and DiffServ [22] have gained little commercial traction in live production networks.

Accordingly, our paper is part of the first step in a 4-part engagement process to conceptualise, engineer and deploy a CIS system that is fit-for-purpose for the 5G era. It (Part 1) involves developing, validating and refining the 999 concept with the research community. This was also the focus of [13]. Part 2 is industry engagement with telecoms operators, standards bodies (e.g. 3GPP) and trade associations (e.g. GSMA) to establish the framework for developing the 999 CIS app and incorporating it into the cellular standards. Several operators (e.g. Japan's NTT DOCOMO) have a history of promoting disaster response solutions and some industry groups (e.g. GSMA's Mobile for Humanitarian Innovation group) already work on articulating and developing solutions for disaster and emergency services. Part 3 is engagement with policymakers to secure regulatory mandate for a smartphone-based CIS system. The authors engaged with the Body of European Regulators for Electronic Communications (BEREC) during the 2018/19 consultation on net neutrality to make the case for a modification of the net neutrality principles to permit prioritisation for CIS. Part 4 is the actual development and deployment of the system and the authors have kicked this off by developing a beta version of the 999 app to begin to explore the different possibilities of deploying it in real live.

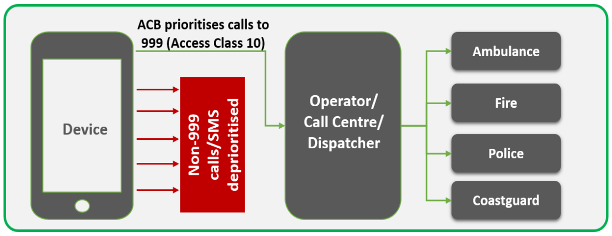

Fig. 4: Architectural design of the 999 call system in the UK

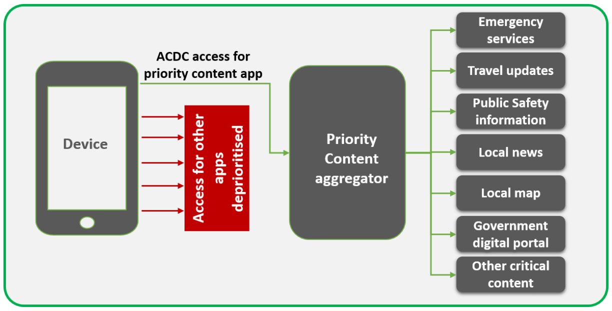

Fig. 5: Proposed design of a 999 app for emergency and critical data services

V. Conclusion and Future Work

Our work is a first step in the development of a standardised smartphone-based system for critical information services. This is necessary because traditional news sources are losing out to new generation alternatives on social media. The paper makes the case for prioritisation as the first step towards providing QoS assurance for CIS and shows the different considerations that will be required to deliver such prioritisation. Of particular note is that reserving a bandwidth of up to 100kbps for delivering CIS messages will be sufficient to deliver a traffic flow of the size of Whatsapp voice without unduly impacting the QoS for other services. This insight provides justification to propose and conceptualise a 999 CIS app which mimics the existing 999 voice system. We acknowledge that the engineering of the 999 CIS system is only a part of what needs to be done to successfully develop and deploy the CIS app. Accordingly, our future work is to further engage with telecoms operators, standards bodies, industry associations and policymakers to drive support to develop the system.

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