**Emergency Service Network (ESN):**

**Investigating whether the ESN network is able to provide the level of service required within the current roll-out timeframe.**

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by

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# Abstract

**Research aims and objectives**

With over 300,000 police, fire-fighters and paramedics relying on the UK’s emergency services communications network (ESN) to perform their tasks, the system must work as close to its negotiated contractual agreement as possible, especially in mission-critical and life-or-death situations, as the security of the nation and the safety of the emergency service workers are at stake and can be compromised if a tool or system fails.

In 2015, the UK government has awarded a contract to the mobile operator EE to provide a new 4G cellular ESN to replace the current Airwave system in 2019/20. However, there have been significant concerns raised regarding the potential robustness of EE’s proposed technical strategy and its ability to be able to match the incumbent Airwave solution. The main aim of this study is to examine the validity of these concerns in depth, with the objective being to determine to what extent they may affect the effective and timely implementation of the new EE technical solution, with the objective being to provide recommendations regarding how the current shortcomings of the system can best be addressed.

**Methodology:**

A mixed methodology has been used for this study, which included an examination and analysis of existing research, together with a small sample of semi-structured interviews of individual stakeholders who are intimately involved with the emergency services communication process, which is supplemented by the researchers own unique knowledge of both the Airwave TETRA system and EE’s 4G network. The benefit of this methodological approach is that it enabled a detail and in-depth understanding of the challenges that the emergency services personnel face when needing to respond rapidly to incidences.

**Findings**

The findings from the research confirmed that the new cellular ESN system operated by EE is not yet in a position to provide the level of service needed to provide the emergency services with a robust and effective communication system that will keep the UK public safe and secure when the ESN system is activated in 2019/20.

**Outcome**

The conclusion of the study was that the new ESN system must be run in tandem with the existing TETRA Airwave system until all remaining risks have appropriate cellular solutions to mitigate them. While this approach will be costly to UK tax payers, it is the only way to ensure the communication system which helps ensure the safety and security of emergency service providers and UK citizens runs within its contractual agreements. Given that the UK’s terror threat level has been at severe since August of 2014 (Scott, 2017) and given the tragic terror attack on Parliament on the 22nd of March 2017, there is a strong likelihood that the ESN system will be put to many mission-critical tests over the next few years and we cannot afford for the ESN to fail.

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# Abbreviations

3ES: Three Emergency Workers

3GPP: 3rd Generation Partnership Project

A2G: Air to Ground

ALU: Airwave London Underground

ARPU: Average Revenue per User

AW: Airwave Solutions

BAPCO: British Association Public-Safety Communications Officials

BT: British Telecom

BTOR: British Telecom Open Reach

BTP: British Transport Police

COLP: City of London Police

Connect 2000: LUL Leaky Feeder and RF Solutions

DAS: Distributed Antenna Systems

DMO: Direct Mode Operation

DNSP: Direct Network Service Provide

End to End Encryption

End Users: Currently 300,000 + Users within the Emergency Services

ERV: Airwave Emergency Response Vehicle

ESMCP: Emergency Services Mobile Communication Programme

ESN: Emergency Services Network

ETSI: European Telecommunications Standards Institute

GCN: Government Conveyance Network

HO: Home Office

IBS: In-Building Solution

ISP: Internet Service Providers

LTE: Long Term Evolution

LUL: London Underground Limited

MNO: Network Virtual Operator

MVNO: Mobile Virtual Network Operator

NAO: National Audit Office

NHC: Noting Hill Carnival

NM: Nautical Miles (1 Nautical Mile = 1.15077945 Miles)

NMC: Network Management Centre

NPIA: National Police Improvement Agency

OFCOM: Office of Fair Communications

PMR: Professional Mobile Radio

PSN: Public Service Network

QOS; Quality of Service

RAE: Royal Academy of Engineering

Resilience: ERV’s, Battery Banks, Neighboured Sites

RF: Radio Frequency

ROV: EE Remotely Operated Vehicles

RRV: Rapid Response Vehicles

RSM: Remote Speaker Mic

SP: Service Providers

T/G: Talk Group

TCCA: TETRA and Critical Communications

TEDS: TETRA Enhanced Data services

TETRA: Terrestrial Trunked Radio (TETRA; formerly, Trans-European Trunked Radio)

TFL: Transport for London

TIP Summit: Menlo Park 1st November 2016

TMO: Trunk Mode Operation

U/P and D/L: Uplink and Downlink

UAT: User Assurance Testing

UDDS: User Device Detailed Specifications (ESN Specific Handset Specification)

UHF: Ultra High Frequency

User to User Encrypted

VHS: Very High Frequency

VSAT: Very Small Aperture Terminal

# Chapter 1: Introduction

## 1.1: Background

The UK’s emergency services, which comprise law enforcement, fire and rescue, and the emergency medical services (Home Office 2015), are critical for keeping our nation safe and secure, by being able to respond immediately to any relevant event. The UK government and its citizens rely on its emergency services for everything from solving domestic disturbances and petty crime to protecting the Royal Family and conducting covert anti-terror operations.

It is apparent, therefore, that the products, services and systems the emergency services leverage to perform their tasks must work flawlessly in mission-critical and life-or-death situations. The security of the nation, as well as the safety of the emergency service workers, are at stake and can be compromised if a tool or system fails.

One of the key systems used by the emergency services to perform their duties is their communication system, often referred to as emergency services communications. The communication system serves over 300,000 police, fire-fighters and paramedics (Williams 2015), enabling them to communicate person-to-person and as a group, with high levels of security and resilience, to coordinate operations in real-time, request back-up assistance as needed and to perform normal, day-to-day tasks as well as tasks which are mission critical in nature.

## 1.2: Research rationale

 For the past decade, a terrestrial trunked radio (TETRA) network has been the system used for emergency services communications. The TETRA network is a purpose-built system, which was specifically designed for use by the emergency services (Williams 2015). The TETRA network is currently operated in the UK by the British communications company Airwave Solutions Limited and branded as the Airwave Network (Airwave 2017), a sub-division of the Motorola Corporation that was awarded the contract by the UK government.

Recent statistics presented by the National Audit Office (2017), indicates that the Airwave network covers 97% of Great Britain’s landmass. The NAO report confirms that during the course of the contract to date, the Airwave has provided an effective means of emergency services communication during reoccurring events, such as the annual Notting Hill Carnival, major one-off events, including the Royal Wedding, the Papal visit and the 2012 London Olympics and, more recently, ensuring rapid response to issues such as terrorism attacks and flooding.

However, the Airwave emergency services communications contract expires in 2019 (Parliament 2017). In advance preparation for the awarding of the emergency services system that will be implemented following the expiry of the current Airwave contract, in 2011 the government set up a Mobile Communications Programme committee, which was tasked with exploring the best option for continuing to provide emergency services communications after the expiration of the Airwave contract. The conclusion of the of the committee was that the current ‘TETRA-based’ system should be replaced by a new form of communication, designated as an Emergency Services Network (ESN) which will provide communications through an existing, commercial 4G network (Home Office 2015). The current plan is that the emergency services will begin migrating onto the new network in September of 2017, with the aim of completing the migration in December of 2019 (Parliament 2017).

However, it is apparent that the shift of the UK’s emergency services communications infrastructure from a purpose-built, private TETRA system to a more commercial and public 4G cellular system is a complex process, and one that is likely to present risks as well as rewards. Consequently, it is important to assess and evaluate the inherent costs of both systems, which from a financial aspect will be met from the UK taxpayer and, more importantly, the costs associated with the quality of the services provided by the emergency services that have been previously identified. In particular, based on the fact that the 4G cellular is still a relatively new technology, which is still being deployed, it is equally important to examine the associated short term challenges as well as the longer term benefits that are associated with the introduction of the new cellular ESN system.

## 1.3: Research aims and objectives

The main aim of the current dissertation is to access the efficacy of upgrading the UK’s emergency service communications from a TETRA to a cellular based system. In particular, the opinion of the researcher is that, the ESN is not yet in a position to provide the level of service required to keep the emergency services and the UK safe and secure. Specifically, in this context, the research aims are therefore based on resolving the following two main hypotheses:

**Hypothesis 1:** *Currently, based on the limitations of the 4G technology and its potential future development, the ESN system is unlikely to provide the level and quality of service the emergency services required in the UK*

**Hypothesis 2:** *There is a need to extend the current TETRA system beyond the 2019 deadline to ensure the continued quality of the emergency services communication process beyond the 2019 deadline*

 A mixed methodology will be used for this purpose, which will include an examination and analysis of existing research, combined with the conducting of two survey processes, these being semi-structured interviews of individual stakeholders who are intimately involved with the emergency services communication process and a survey questionnaire sent to stakeholders as well. The benefit of the latter approach is that it will provide another layer of understanding of the key benefits and challenges.

 To facilitate the resolution of these hypotheses, a number of objectives have been set for the research project, which has included the following:

* To examine the scope, features and functions of the existing Airwave TETRA network, scrutinizing the quality of service (QOS) the current Airwave TETRA network provides, including how the service is tested. The associated costs of the Airwave service will also be highlighted.
* To explore the motivations for migrating to the cellular-based ESN and the benefits the ESN service will bring.
* To analyse the process of upgrading the UK’s emergency service communications from the Airwave TETRA system to cellular-based ESN and highlight the key issues associated with this change of approach. For this purpose, a mix of quantitative and qualitative research methodologies has been used.
* To assess what needs to be done to ensure the UK’s emergency services network communications system can run smoothly, safely and securely in the short term and longer term.
* To identify the implications that this change of communication process will have on the QOS of the UK emergency services and to provide recommendations regarding improvements that need to be considered to improve the outcome of the intended change of emergency communication systems.

## 1.4: Research contribution

It is anticipated that the outcome of the current study will provide a positive contribution in two main areas, which include its contribution to the current literature debate regarding the effectiveness of using the 4G system as a foundation for emergency services communications and, additionally, the researcher’s knowledge related to the issues being focused on in the research project. In terms of the existing research, it is anticipated that the outcome of the study will provide positive recommendations related to the security and efficiency of the communication that should take place between the initial public contact related to their immediate need and the speed of communication between the central emergency centre and the emergency forces deployment of their practical resources.

The researcher, who is a technical consultant, has personal experience of working with the Airwave TETRA system as a test engineer and technical consultant between 2008 and 2017, has been involved in events such as the 2010 Papal visit, the 2011 Royal Wedding and the 2012 Olympics, and therefore has a strong understanding of its strengths and weaknesses. However, while having a strong understanding of 4G from a coverage, security and resilience perspective and a unique point of view of the relative strengths and weaknesses of 4G, the research has a limited knowledge of the positive benefits available from this system. Therefore, the study will serve to enhance and improve his knowledge and expertise in this respect.

## 1.5: Structure of dissertation

 Following this introductory chapter, the remainder of the dissertation has been structured across a number of chapters. Chapter two provides a review that examines the current literature related to the issues that are being addressed in the study, and which provides the foundation for the research aims and objectives. Chapter three presents an overview of, and justification for the methodologies that have been adopted for the current research process. In chapter four, the findings resulting from the analysis of the data are presented. An analysis of the findings in relation to the research aims and the outcome presented in the literature review are then discussed in further depth in chapter five. Chapter six brings the study to a conclusion, where the implications of the findings for the implementation of the new ESN are identified and the issues requiring further research are identified.

 In addition, a list of sources relied on during the study, together with appendices, which presents information that can improve the understanding of the issues that have been discussed in the main body of the study, have been attached.

##

# Chapter 2: Literature review

## 2.1: Introduction

 The review commences with a brief overview of the emergency services communication protocol followed by an overview of the TETRA system, including its strengths and weaknesses, followed by a review of key literature surrounding the decision to upgrade from the TETRA-based Airwave system to the 4G-based ESN system. The review then provides an overview of ESN, highlighting its relative strengths and weaknesses and details the proposed transitional process from Airwave to ESN. The final and most important part of the literature review focuses on literature to date which highlights concerns with the timing of the ESN rollout.

## 2.2: Emergency services communication protocol

 As noted in the introduction, the effective operation of inter-organisational and inter-personnel emergency service communication is critical in terms of its effective and efficient response to major events and crisis situations throughout the UK (IFAC 2005). Of equal importance within this context is the need for this level of communication efficiency to occur between the three major emergency services networks that have been identified, namely the police, fire and rescue and emergency medical healthcare services, as well as other appropriate organisations. In this respect, therefore, the communication protocol has to be both inter-organisational and intra-organisational. Inter-organisational communication relates to the process that allows members from the same organisations to maintain contact with other members of their team during the response period required for the major event or emergency crisis. Intra-organisational communication allows communication between the three emergency services during such events and incidents, which is required to ensure the quality of the interaction that is required to deal with the incident.

## 2.3: The TETRA (Airwave) system

 The Airwave TETRA network is the first UK network to allow all three emergency services – the police, ambulance and fire brigade – to communicate amongst each other (Cole and Hawker 2014). Prior to this time, even various regions of the police force communicated on different systems. The Airwave TETRA network was rolled out across the UK between 2001 and 2005, and by 2011 all emergency service personnel in all regions of the UK were using the system. The Airwave network is a propriety network, which was custom-built for the emergency services and which was developed under a range of contracts agreed with the government. The network operates on dedicated frequency bands of the spectrum: 380-400MHz along with 410-414MHz and 420-424MHz for Direct Mode Operation (DMO), which can be activated when the Airwave network is inaccessible. The main spectrum bands used by the Airwave network are owned by the North Atlantic Treaty Organization (NATO) and reserved across Europe specifically for Emergency and Public Safety Services. As detailed previously, the Airwave network operates on Terrestrial Trunked Radio technology radio system, which is a private mobile radio standard defined by the European Telecommunications Standard Institute (ETSI) (RF Wireless World 2014). Within the TETRA network, users can communicate to other users directly or via a base station. The TETRA network interfaces consist of Air Interface, which ensures interoperability of equipment from different manufacturers, Terminal Equipment Interface (TEI), which enables the independent development of mobile data applications, Direct Mode Operation (DMO), which guarantees communication between terminals, and Inter-System Interface (ISI), which enables the interconnection of TETRA networks from different manufacturers.

Figure X: The TETRA Network Interfaces



 *Source: RF Wireless World (*[*http://www.rfwireless-world.com/Tutorials/TETRA-radio-system.html*](http://www.rfwireless-world.com/Tutorials/TETRA-radio-system.html)*)*

As mentioned, Airwave is the sole provider of the UK’s emergency services communications network, as contracted by the Home Office. As noted by the government, “*These contracts cover 105 emergency services in Great Britain as well as 307 other public sector organisations* (National Audit Office 2016). The firm has estimated that its coverage extends to 99% of the UK landmass, therefore being accessible in almost any location throughout the entire country, although recent government documents have suggested that the coverage is closer to 97%, which is still impressive (Home Office 2015).

### 2.4.1 A Brief Overview of the Advantages and Disadvantages of the Airwave TETRA System

 The main benefits of the Airwave emergency services communication system have been advised by the corporation as applying to five main factors:

* Coverage
* Resilience
* Capacity
* Interoperability
* Security

These are deemed to apply to its extensive landmass coverage and, as noted earlier, to its being a dedicated system for the UK emergency services, as well as its responsiveness and resilience, interoperability and security. In terms of coverage, irrespective of the differential between Airwave and the government in this context, at a minimum of 97% coverage is impressive. Furthermore, the overland and underground access of the Airwave system means that the emergency service personnel operating in enclosed or underground environments can continue to maintain communication with their colleagues and members of other emergency teams on site (Fischer and Gellersen 2010).

 Interoperability benefits are promoted as a benefit in that the system allows members of the emergency team, through both the central emergency service communicators and, while on site, to communicate and interact positively with members of other emergency teams’ onsite. For example, the police are able to communicate immediately with the fire and ambulance service personnel and vice-versa (BT 2011). The interoperability techniques are normally setup within the fleet plan, once there is an incident and the need for interoperability is required then the Gold, Silver Bronze Command Centres will issue Talkgroups as required.

 Security issues are addressed by the fact that this system is dedicated to and only accessible by the emergency services and other organisations that it was designed for, while at the same time able to be accessed inter-operational organisations within this service group (Sterle et al 2015). In summary, specialist organisation, Bradbourne Communication (2017, n.p) have that there are five main benefits that attract to the TETRA system, which they identified as follows:

* *It effectively combines voice and data communication in one handset,*
* *The encryption process provides security of voice and data communications,*
* *Direct mode – The radios can be operated in unison, without the need for the existence of an external network*
* *In terms of resilience, the system includes a number of fall back options that serve to reduce the risk of communication failure*
* *Gateway access – The system allows for connection to another network, which can extend it coverage and range*

*Source: Adapted from Bradbourne Communications (2017)*

 The Airwave TETRA system is not without disadvantages however (Bradler 2009; Ferrús and Sallent 2015; Williams 2015). Among the most important of the criticisms that has been levelled against the Airwave emergency system are the following concerns:

* Potential failure of the landline system, which forms a central element of the communication process between various emergency response teams
* The current Airwave system is not as future-proof as other networks, such as an LTE network which can take advantage of advances in technology for services like live streaming video images
* The cost to the government, which has been estimated at £450 million per annum

## 2.4: The reasons behind the upgrade from the TETRA (Airwave) system to ESN

One of the earlier pieces of proper literature published onthe weaknesses of the Airwave system which provided suggestions on how to effectively upgrade it for the future communication needs of the UK’s emergency services network was a Memorandum submitted by the Royal Academy of Engineering which formed part of the appendix of a House of Commons Home Affairs Committee (2008) report, the Royal Academy of Engineering concluded that to date the Airwave system had been fairly successful in handling the communications needs of the emergency services network.

That said, the Royal Academy of Engineering concluded that the Airwave system would be inadequate for the future needs of the police force. The Royal Academy of Engineering argued that the platform was primarily used for voice communications and that the volume of voice traffic was already reaching the limits of the Airwave system’s spectrum resources in specific areas such as London. The Royal Academy of Engineering highlighted that the Airwave system had narrow bandwidth and data capability and that in order to carry more voice traffic, additional spectrum would be required. The Royal Academy of Engineering noted that even if additional spectrum were to be added, it would likely not be adequate to cope with future policing needs. The Royal Academy of Engineering put forth that a wireless broadband technology system, such as Worldwide Interoperability for Microwave Access (WiMAX), would be necessary to cope with the increased data transmission needs of the police force and asserted that applying the military concepts of Network Centric Operations (NCO) to policing would create a true step-change in UK policing, enabling officers to deter and defeat criminals and terrorists by attaining and maintaining information superiority through the rapid, accurate distribution of data between officers. The Royal Academy of Engineering detailed that the NCO approach would require a local encrypted network with broadband capability and mesh technology, highlighting that the replacement system for Airwave would need to be reliable and secure as well as increase coverage between officers, vehicles, stations and control centres.

In 2010, the UK coalition government initiated an austerity programme (Elliott and Wintour 2010) with the aim of reducing public spending and Airwave came under the spotlight as one area were savings could be made. In December of 2010, Wireless Magazine (2010) published the key points of a TETRA Round Table on the subject of ‘How Will TETRA Fare in the Spending Squeeze?’ While several of the round table attendees were undoubtedly biased in their perspective as they were senior employees of the TETRA organisations or from Airwave, the round table also included Sue Lampard, a VP from the British Association of Public Safety Communications Officers (BAPCO) and Duncan Swan, a Partner at Analysis Mason, a global consulting and research firm which specialises in telecoms, media and digital services. One of the key take aways of that round table was that TETRA would remain the technology of choice for the next decade (at least until 2020). This conclusion was based on points raised including the concern that there was not enough spectrum in Europe to deliver LTE and that the mobile devices which would be used with LTE would not be adequately robust, ‘cop proof’ or have a decent battery life. Rodrigo Franciscani, a Senior Strategy Manager of Motorola Solutions, hypothesised at the time that TETRA would need to be the emergency services communications technology of choice for the near future because of its resiliency, call set up times and comprehensive group call features and that LTE would be introduced as a broadband data overlay.

In 2011, the UK government set up the Emergency Services Mobile Communications Programme (ESMCP). Conference proceedings from a 2012 Cambridge Wireless Event titled Emergency Services Mobile Communications Programme outlined that the objective of the ESMCP was to review the emergency services future voice and data needs, specifically from 2016 onwards, with a focus on providing a voice and data service solution, which was both cost effective and mission critical (Home Office 2012). As part of this, there was an objective to ensure an open and competitive environment for the delivery of emergency communications services as well as flexibility and continuity.

On June 13th, 2013, the Home Office published a document (Home Office 2013) detailing that the services currently provided by Airwave were to be replaced with a new national mobile communications service called the Emergency Services Network (ESN). As per the NAO report (NAO 2016), ESN will save tax payers money by sharing an existing commercial 4G network and will deliver better mobile-data capabilities than possible via Airwave.

Concerning the contract process, as noted in the report prepared for Parliament (2017), whereas the government had a single contract with Airwave, for the new ESN system the bidding process was “*disaggregated into several contracts that were competed individually.29 The two main contracts were to provide user services (the public service applications and new technology to run ESN) and to provide the mobile network*” (Parliament 2017: 13). Of these, Motorola was successful in bidding for the user services contract and EE (BT) was successful in securing the mobile network contract.

### 2.3.2: A Brief Overview of ESN

 In contrast to Airwave, the ESN communications system is based on 4G cellular mobile communication protocol (Ferrús and Sallent 2015). As noted by Schulzrinne and Tshofenig (2013), the system relies on a three stage approach within the communication process, the first of these being the development of an emergency services IP network. This network receives the calls and then transfers them to the emergency service communication provider, and the message is then sent to the relevant location, in much the same way as the current Airwave services does. However, as noted above the ESN system will also share a network with the public (Parliament 2017: 11).

Figure 1 Mobile emergency services communication systems



*Source: Schulzrinne and Tshofenig (2013: 6)*

### 2.4.2 A Brief Overview of the Advantages and Disadvantages of ESN

 It has been argued by Schulzrinne and Tshofenig (2013), that there are four main benefits to changing to the IP-based system of emergency communications, which are:

* *Lower costs due to the commodity nature and increased competition,*
* *Lower operational costs compared to the legacy (circuit-switched) infrastructure,*
* *Future-proofing since the rest of the entire industry is moving to IP as well, and*
* *More functionality and better extensibility*

*Source: Schulzrinne and Tshofenig (2013: 6)*

A network of interactive displays offers new possibilities for effectively communicating with a target audience (Davies et al 2012: 6). In this context, the benefit of the mobile technology system is that it can provide the emergency service engaged in the conversation with important advance information, such as visual images of the scene being reported, or in the case of injury, a visual image of the patient’s condition (Davies et al 2012). Such advanced information enables the emergency responder to ensure that the right tools, equipment, medication and manpower delivered in response to the incident (Ferrús and Sallent 2015). Initially it is anticipated to cost the government around £240 million a year, which in itself represents a significant saving on the Airwave system (Williams 2015). Equally, the advent of GPS, mobile phones and effective waterproofs has meant that personal technology and equipment is playing a stronger role, however, at the same time, unless secured, this poses an increase in the perceived risks attributable to these systems (Yarwood 2010). In addition to the cost benefit identified, the Home Office (2015: n.p) suggests that the main benefit of the move to the ESN system is that it “*will be a mobile communications network with extensive coverage, high resilience, appropriate security and public safety functionality. This allows users to communicate even under the most challenging circumstances*”.

 However, there are also challenges associated with the proposed new system. For the ESN system, one of the major challenges to be faced is the potential for cyber-attacks, which can affect the mapping system itself, and the individual provider (Loukas et al 2013; Schulzrinne and Tshofenig 2013). Another issue is that the 4G system proposed is shared with the public. The only other system of its kind is operating in South Korea, and this is not shared with the public, therefore increasing its security.

## 2.5: The proposed transitional process from Airwave to ESN

 In setting out the parameters for the ESN contract, the UK departments and the Home Office (2015) identified a number of objectives that the selected contractor needed to achieve to fulfil their project obligations. Among these conditions two important elements were included, the first of which related to integration, the conditions of which included:

* enhanced: to provide integrated broadband data services
* flexible: to better match and be responsive to user needs
* affordable: to address financial pressures on central and user budgets
* air to ground (A2G) network
* control room upgrades, this may require:
* upgrading the 200+ integrated command and control systems
	+ connection to the public service network
	+ connection to mobile data systems, fire mobilising systems and command and control systems

Additionally, in terms of extended area services, the project was required to take account of the following:

* the mobile network operators commitment to provide 98% in building coverage by population
* the mobile network operators commitment to provide 90% geographic coverage
* the mobile infrastructure project, a government initiative to improve rural mobile coverage

*Source: Adapted from (Home Office 2015)*

 Furthermore, a designated timescale was also set for the project and the completion of the transition process (table 1).

Table 1 ESN system timeline



*Source: Parliament (2017: 9)*

 The purpose of including a transitional period was to allow the various emergency services time to familiarise themselves with the new system as well as the opportunity to test the quality of its operability by running it in parallel with their existing system for a period of time before the target changeover date is reached (Parliament 2017). As will be noted from the following diagram (figure 6), these transitional periods varied across geographical regions.

Figure 2 The transitional process by geographical area



*Source: Parliament (2017: 10)*

## 2.4: Concerns with the timing of the ESN rollout

While almost all government bodies and public companies agree that LTE is the way forward for emergency service communications, several industry experts and organisations have raised key concerns surrounding the nature of the plans the Home Office has put in place to replace the existing Airwave TETRA network, particularly the ambitious timeline for the roll-out.

A 2013 white paper by Germany’s interior ministry concluded that mission critical networks comprised of broadband voice plus data would, at the earliest, be ready to leverage by 2025 (Federal Ministry of the Interior 2013). In 2014, the Financial Times (Warrell 2014) reported that Labour had warned the Home Office that the speed of the Airwave replacement programme would put public safety at risk and that the ‘unseemly haste’ to finalise the contracting process left no time to test the programme.

Former head of the National Policing Improvement Agency, Peter Neyroud, also voiced concerns over rushing through the new service, especially one involving companies with no experience of coordinating emergency services communications. Neyroud was quoted as saying *“It’s surprising that [the Home Office] would take a risk like this on a service where you might have an officer in a firearms incident needing to communicate. It has the feel of some of the NHS IT programmes where people where in such a rush that they didn’t give themselves the elbow room to sort out the problems…”* At that time, the Home Office confirmed it was on track to start the new network in 2016/17 and mobile operators confirmed that their 4G networks would be in place to connect the first police forces by 2016, with roll out to the whole country in place within the next 12 months (with the Airwave TETRA network running alongside the new 4G service between 2016 and 2017).

During the ESN bidding process, concerns about the projects timeline were flagged by several of the bidding parties. When Airwave submitted its bit for Lot 3 of the project, the company outlined (Scroxton 2015) what they felt to be key risks with the project and made clear that they did not feel the timeline was achievable. O2 withdrew from the Lot 3 bid siting almost identical concerns. Hewlett-Packard also withdrew from the Lot 2 bidding process, again citing concerns over the timing of the project (Scroxton 2015). The company believed it would not have been able to meet *“the programme’s requirements and timelines with a level of commercial and technical risk that was acceptable to all parties”.*

After the ESN bidding process, when Airwave filed court documents as part of their claim for damages for being dropped as a bidder, news sources like the Guardian (Travis 2015) immediately reported that the documents revealed issues with the scope of services to be offered by the ESN, raising red flags over to the robustness of the new network. According to these court documents, the EE ESN contract did not include:

* An immediate requirement to provide 4G coverage on the London Underground Rather, the contract detailed that EE would need to provide a roadmap for delivery of ESN services within the London Underground in the eventuality that LTE is installed in the London Underground.
* The requirement to provide coverage in rural areas including *‘approximately 5km of major roads, 399km of minor roads and the exclusion of minor road areas below 300 meters where the probability of a signal is less than 50%.’* which, Airwave flagged, would leave large parts of Wales and rural Scotland uncovered by the new service.
* A provision for the police and emergency services to get network priority over the public during major events, such as a terrorist attack

In October of 2015, Airwave COO, John Lewis, spoke out about ESN (Scroxton 2015), stressing that, while *“4G LTE is the system for the future of public safety communications…it is not the best system currently.”* He argued that TETRA is a proven and trusted mission-critical voice system and outlined what he felt were several risks with the ESN programme, namely:

* Standards: Lewis highlighted the standards for mission-critical voice over LTE (VoLTE) have not yet been agreed or specified and will not be until sometime after TETRA is switched off in 2020. With the implications being that key emergency services communications features such as handset-to-handset communications, group calling and push-to-talk (PTT) would not be ready in time for the final switchover to ESN. Lewis did note that the government is trying to address the lack of standards via using pre-standards systems, but pointed out that deploying such pre-standards systems, which have yet to be deployed anywhere in the world on a scale such as this, would be a high risk approach.
* Coverage and Resilience: Lewis also pointed out that 4G LTE networks are still being rolled out and do not yet cover the entirety of the UK, especially the remote areas. Given his experience in building the TETRA network, he argued that the timeframe the government had given for the ESN project would not be sufficient to roll out the new network, pointing out that it is too risky to assume 4G will be fully available by 2020.

A November 2015 presentation by the Home Office confirmed that the programme objective was still to have ESN available for use starting in 2017, with the rollout complete by 2020 before the Airwave contract is set to expire (Home Office 2015). The presentation also confirmed that the new system would *“meet all user, system and commercial requirements, but not necessarily in the same way as Airwave.”* The presentation did state that, as an ‘interim solution for the London Underground, the programme would continue to use Airwave below ground with TfL implementation of 4G LTE technology as a ‘long-term solution’ though it did not specify for how long the ‘interim solution’ would be in place. The main ESN contracts were signed in December of 2015.

In March of 2016, the UK Home Office and its ESMCP team made its first public appearance at the British APCO event (BAPCO 2016). Steve Whatson, Deputy Director Delivery of the ESMCP programme assured delegates that ESN would match the coverage provided by Airwave (Atkinson 2016) including 96% coverage for major roads, 87% coverage for minor roads, 87% coverage for outdoor portable handheld devices and 87% coverage for marine environments. Watson confirmed that ESN coverage would be comprised of a number of elements, which would be meshed seamlessly into one network run by EE, with the elements including:

* EE’s main commercial 4G network
* Extended Area Services (remote areas of the UK where new passive sites need to be built under a separate contract and then equipped with EE base stations)
* Air-to-Ground AW 6 LTE 12
* London Underground
* Crossrail
* Marine coverage – to 12 nautical miles
* Special coverage solutions

Watson also confirmed that like-for-like services were in the process of being accomplished via the following approaches:

* Extended Area Services (EAS) and EAS Backhaul: Whatson stated that six to eight companies would be competing to acquire, design and build the additional sites and that they were looking for backhaul solutions in conjunction with Motorola. Whatson outlined that satellite backhaul solutions were being explored as well as fibre and microwave wireless solutions, which would *“connect the sites to the main network via mini-hops.”*
* Air-to-Ground services: Whatson provided a small number of details regarding the ESN A2G solution, which was comprised of using TDD (Time Division Duplex) spectrum.
* London Underground services: Whatson confirmed coverage to LUL underground stations would be provided via either a 4G card in Wi-Fi access points or via deploying a separate 4G base station alongside them with coverage out to the road to make it a seamless part of the EE network. He also confirmed there were plans to use the existing Leaky feeder cable within the tunnels, therefore connecting into the LUL Connect 2000 system due to space issues within the tunnels.
* Direct Mode Operation (DMO): Whatson conceded at the event that DMO might not be in handsets by the time emergency service network users start transitioning to ESN and that back-up plans would likely be needed. One of the alternate options being considered as of March 2016 was dual-mode devices, which would harness both TETRA and LTE, though no details were provided as to if these dual-mode devices, would be needed beyond December 2019.

At that same event, Mansoor Hanif, Director of Radio Access Networks at EE, outlined some specific approaches EE was taking to ensure the ESN service will be like-for-like with Airwave. He detailed that, in order to facilitate a like-for-like service, the company was working on solutions in the following areas:

* Coverage and capacity: Hanif stated that EE were building out their network to comprise some 19,000 sites and some smaller sites. He also argued that EE have 20 times more spectrum than Airwave, including some 800MHz spectrum, which propagates over longer distance and is better at penetrating buildings than other spectrum holdings. He also highlighted that VoLTE would have a positive impact on coverage and capacity, with low dropped call rates.
* Resilience: Hanif highlighted that EE were deploying a range of solutions including battery backup, fixed and mobile generators, resilient transmission, flood defences and rapid response vehicles to ensure network resilience. With regards to transmission resilience, EE stated they were implementing *‘multiple routes back to the network to connect every base station to the core network.’* These paths would be made up of wireless links, satellite and leased lines. EE also confirmed they were exploring how Airmasts could be used in emergency situations.
* New Operational Procedures: Hanif noted that new legislation would help improve EE’s access rights to sites so any site problems can be remedied quickly.
* Mission Critical Standards for LTE: Hanif confirmed that the mission critical features in 3GPP Release 12 would help enhance and support EE’s 4G security, allowing the network to prioritise calls and deliver a high availability for resiliency. He noted that 3GPP release 13 also includes a standard for mission critical PTT functionality.
* Rural Coverage: Hanif put forward that EE were exploring technical options to close gaps in remote areas, such as the use of portable masts delivered to/held in position via blimps and drones, mobile LTE network-in-a-box solutions, marine ROVs for flood areas and satellite backhaul.
* Backhaul in Remote Areas: Hanif stated that EE are exploring deploying rural small cells with satellite backhaul for areas were they don’t have backhaul, such as the Scottish Highlands and the Welsh Valleys, as a temporary / back-up solution when the main solution fails and for some of the remotely operated vehicles (ROV’s) where needed. As part of this, Hanif reported that, while normally it takes 480ms to complete a round trip via satellite, recent EE proof of concept trials carried out with partners has achieved 100Mbs speeds. Hanif also detailed that EE would be able to exploit some small cell products from their parent company, BT, as well as leverage Open Reach telegraph poles for their for small cell mesh technology.
* Major Events (Disaster Recovery and Emergency Response): Hanif put forward the EE would possibly be using Airmasts to provide additional coverage during such major events. Hanif did not outline EE’s approach for planned major events (e.g., Notting Hill Carnival) but one would assume the approach might be the same.
* Maritime Coverage: Hanif stated that EE was exploring mesh network techniques to enhance 4G maritime coverage. He detailed that EE was experimenting with connecting the 43 ferries that sail between the Scottish Islands via deploying small cell solutions on the ferries, which then mesh to small cells, which EE were positioning on surrounding lighthouses with power.
* Indoor Coverage: Hanif outlined that EE had 4G small cells and DAS solutions ready ‘to pull the trigger on’ but did not provide definitive answers on whether this system would be using routers or another technology to ensure proper integration into the macro network.
* Testing: Hanif put forward that the ESN test plans would include drive testing, an app-based solution (which he noted would only measure where the end users actually go) and geolocation statistics from the network which would then be triangulated.

While Hanif and Whatson’s debrief went some way to detailing which technical solutions ESN would employ to ensure the new network would provide like-for-like mission critical coverage, the information they provided did not detail the timing of these solutions and thus, one can argue further questions were raised off the back of this briefing.

 By the summer of 2016, news sources were reporting that a full transition to a 4G ESN network by the end of 2019 was increasingly unlikely (Hall 2016). Gordon Shipley, director of the ESMCP, confirmed at the 2016 Critical Communications World exhibition in Amsterdam that a plan was in place to continue leveraging the Airwave network *“for as long as it takes”* in case there were to be delays to the EE roll-out and that the new ESN network would not *“go live unless we have demonstrated to…users the system works as intended and [the users] are content to start transition.”*  Peter Neyroud was also quoted at the event as saying *“the [ESN] completion date was never do-able.”*

The September 2016 NAO report is the most extensive, credible piece of literature on the challenges of the ESN programme as it is currently being rolled out. As per the background section of this dissertation, the NAO report detailed three main categories of risks in addition to the overall risk due to the ambitious nature of programme’s timeline – technical, user take-up and commercial arrangements – which will be expanded upon further here.

Concerning technical risks, the NAO report highlighted the following challenges relating to the ESN programme:

* Coverage: In order to meet the needs of the emergency services, the NAO report outlined several coverage requirements which EE still needed to meet in order to service the needs of the emergency services, namely:
	+ Landmass Coverage: EE still needed to increase the percentage of landmass covered by the company within Great Britain from 70% (as of July 2016) to 97%.
	+ LUL Coverage: A solution still needed to be developed as of the time of the report.
	+ A2G Coverage: A communications solution for helicopters and aircrafts still needed to be developed as of the time of the report.
	+ Resilience: Elements of the resilience of EE’s network still needed to be improved as of the time of the report.
	+ Capacity: Capacity in specific locations needed to be improved to match that of Airwave as of the time of the report.
* Devices: In order to transition to a 4G ESN, new handheld and vehicle-mounted devices still needed to be developed (as they do not currently exist).
* Software: In order to meet the needs of the emergency services, new push-to-talk (PTT) software and ‘group-call’ applications still needed to be developed to facilitate radio-like communications between control rooms and emergency service personnel. The NAO report also flagged that the ESN end-to-end solution would require more points of network integration and still required software, which would enable all the networks to work together, reliably and with sufficient capacity.
* Prioritisation protocols and software: In order to ensure a robust service, especially during major events where capacity is often an issue, new software and protocols still needed to be developed which would give emergency personnel priority over commercial users of EE’s network. The NAO report noted that software and standards for prioritization already exist but had yet to be deployed by the EE network as of the time of the report.

The report highlighted that there remained a risk that the programme would not be able to overcome those technical challenges within the proposed timeline for the role out of the ESN.

With regards to the risk of user take-up, the NAO report highlighted the fact that the emergency services are in control of deciding when they transition to ESN and that the individual units of the emergency services have the freedom to stay on the Airwave system until they agree that ESN is ‘at least as good’ as the service Airwave provide. The NAO report raised two valid points as to why gaining this agreement might prove difficult:

1. Emergency service personnel have high expectations of what ESN should deliver based on the level of service provided by Airwave, including the extensiveness of Airwave’s coverage, the resilience of the Airwave network and the functionality of the Airwave network (such as device-to-device voice calling).
2. The contracts for ESN lack clarity in terms of which areas of the country need to be covered by the ESN network (the contracts only state that the overall coverage standard of 97% need be matched) and what specific Airwave functionality needs to be replicated as part of the ESN network.

The report highlighted the fact that even if a small portion of the emergency service personnel feel that ESN is not ‘at least as good’ as the service Airwave provide, they have the freedom to remain on the Airwave system, which means the overall programme will be delayed and the cost savings of switching off the Airwave system won’t be realized within that time period. The NAO report also found, through interviews, that emergency service personnel were concerned with the timeline for the delivery of ESN and felt that the September 2017 to December 2019 transition period would not be a sufficient amount of time in which to plan and learn the necessary lessons which would allow them to fully switch from Airwave to ESN by December of 2019. This makes the likelihood of a full transition to ESN by December 2019 even more questionable.

Concerning commercial arrangement risks, the NAO report highlighted that ESN has a complex set of commercial arrangements, from its overall commercial structure to how financial risk is allocated.

## 2.6: Summary

 The literature review demonstrates that, while most companies and individuals agree that transitioning the UK’s emergency service communications system to a 4G LTE network is the right long-term move, with many advantages, there are key concerns as to whether the 4G-based ESN network will be able to provide a like-for-like service as compared to Airwave within the timeframe allocated. The literature review shows that there is significant difference between the technologies behind each network as well as how the Home Office is contracting the services. It also shows that that various individuals and reputable organisations, from Former head of the National Policing Improvement Agency, Peter Neyroud to the National Audit Office, have questioned the aggressive timeline under which the ESN programme is being rolled out. Finally, the literature review demonstrates that, while several members of the ESMCP team, including Mansoor Hanif, Director of Radio Access Networks at EE and Steve Whatson, Deputy Director Delivery of the ESMCP, have provided some details as to how ESN will meet some of the challenges that come with providing mission-critical communications, there is a lack of clarity around when these solutions will be in place and a need for further analysis to understand what else needs to be considered before the UK can fully transition from the Airwave network to ESN. Thus, the focus of my dissertation is to provide like-for-like comparison of how Airwave currently achieve mission-critical coverage vs how ESN are proposing to achieve this coverage against several key defined areas in order to outlinewhat specific technical aspects of the ESN programme need further consideration in order for the emergency services to confidently, fully transition from a TETRA-based network to a cellular-based network.

# Chapter 3: Research methodology

## 3.1: Introduction

 This chapter provides and explanation of and justification for the methodology that was adopted for the current research study. The first section of the chapter (3.2) provides an overview of the research approach adopted. Section 3.3 explains the manner in which this approach contributed to the methods of data collection, with the following section (3.4) identifying in more detail the process adopted for the analysis of the data. Sections 3.5 explains how ethical issues related to the methodological approach were addressed by the researcher and explains the limitations that apply to the adopted methodology

**3.2 Research approach**

As noted in the introduction, the research aim was targeted to resolve the two main hypotheses, which were:

1. *That due to the current maturity of 4G technology and the current status EE’s 4G network, further work and validation is needed to ensure the EE ESN service is ‘at least as good as’ the incumbent Airwave solution, and therefore;*
2. *There is a need to extend the current TETRA system beyond the 2019 deadline to ensure the continued quality of the emergency services communication while 4G technology matures and EE put in place and test solutions to the point where emergency service personnel are confident that the ESN service is indeed as good as the incumbent Airwave solution.*

It has been suggested in the literature that the methodology adopted for a study of this nature, which is focused on real world experience (Robson 2002), can be founded on one of two main approaches, which are defined as the quantitative or qualitative method (Fisher 2010; Punch 2013). However, more recently, as observed by Saunders et al (2015), increasingly research scholars are adopting a mixed method approach, which combines these two approaches. Due to the complexity of the current study, and the quantity of the current literature available focused on examining the new ESN system, the mixed method was considered appropriate in this case. One of the main benefits of the adoption of this choice was that it further allowed the researcher to implement a case study process (Yin 2013), which in this case was based directly on the examination of the new EE ESN system, which is set to replace the current TETRA model in late 2019.

## 3.3 Data collection

 Based on the chosen methodological approach, the models used for gathering the requisite data for this research consisted of secondary and primary data collection processes

### 3.3.1: Secondary data collection

 Secondary data collection relates to the gathering, examination and analysis of existing research that is directly related to the study subject matter (Bell and Waters 2014). In this respect, the latest official EE and ESMCP statements on their planned approach to ensure the ESN service would be as good as the incumbent solution, as well as current reports on the subject published by the NAO and other government organisations and stakeholder groups, such as the transcript of a select commons committee meeting from December of 2016. Additionally, it has included the latest research data available from articles published in journals and other related information.

### 3.3.2: Primary data collection

 In contrast to secondary data, primary data is considered to relate to raw data collected directly by the researcher (Creswell 2014). Within this context, the collection process consisted of two main factors, which were the use of a case study approach, as indicated earlier (Yin 2013), and the conducting of two survey processes, these being a survey questionnaire and semi-structured interviews, which were individual stakeholders who are intimately involved with the emergency services communication process. The questionnaire which was utilised for this purpose, and on which the interview process was founded, consisted of a range of open and closed questions (See appendix 1), which were designed to gather the in-depth perceptions of the participants (Saunders et al 2015).

## 3.4: Sample population

 The population who responded to the survey questionnaire and participated in the interview process consisted of a sample of individuals who work for a range of organisations operating within the sector (see appendix 2, question 1), and have intimate knowledge and experience in the technology sector, specifically as this related to ESN systems. In total, 10 individuals responded to the questionnaire, and five individuals agreed to participate in the semi-structured interviews, who are denoted in this study as INT1 to INT5.

## 3.5: Data Analysis

 To facilitate the analysis of the primary data that was collected, an interpretive approach was adopted for this purpose (Creswell 2014). The benefit of this analysis model is that it enabled the researcher to identify the main themes emanating from the analysis of the data, based on the considerations and opinions of the participants (Fisher 2010; Bryman and Waters 2014).

From the examination of the data collected, six main themes were identified for critical analysis of the robustness of the ESN system and the ability of the operators to address the potential challenges identified. These were based on the key points raised by EE and ESMCP at the BAPCO event, the key categories of concern raised within the NAO report, the participants’ responses and the researcher’s own understanding of the incumbent Airwave system and EE’s 4G network as it currently stands. These six categories included:

* Coverage - seven aspects, including:
	+ Remote / rural coverage
	+ Backhaul coverage in remote/rural areas
	+ London Underground coverage
	+ Maritime coverage
	+ Air-to-Ground coverage
	+ In Door coverage
	+ Major Events coverage
* Capacity
* Risk reduction
* Technology considerations
* System testing
* Customer engagement

For each of the categories, the proposed ESN approach, based on the latest official EE and ESMCP statements on the subject, information from the NAO report and information gathered from stakeholder interviews and surveys, was examined and compared to the existing Airwave solution for providing mission critical communications. Further considerations were noted to outline what additional elements should be considered in order to ensure the ESN system is ‘at least as good as’ the incumbent Airwave. The benefit of this approach is that it provides the first, organised, in depth critical comparison of the EE and ESMCP approach to ensuring ESN is ‘at least as good as’ the Airwave service vs the actual Airwave service.

## 3.6: Ethical considerations

 As indicated by Keith Punch (2013: 38), one of the key foundations for an academic study is to ensure that its conduct is founded on appropriate “*ethical principles”*. In the context of secondary data collection, the main ethical considerations were to ensure due consideration was given to complying with the copyright requirements of the data collected and that the selected data was not subjected to bias (Bryman and Waters 2014; Saunders et al 2015). In this case, the selected research documents and information was freely available in the public domain and/or provided within reports provided by experts within the relevant security and technology sectors and government departments. Bias was addressed by ensuring the inclusion of varied views and experts opinions from a varied range of stakeholder groups.

 Within the collection of primary data, a number of ethical considerations arise, which mainly related to privacy, confidentiality and data protection (Creswell 2014; Saunders et al 2015). To comply with ethical principles within this context, several steps were taken by the researcher. In the first instance, the purpose of the research was explained to the potential respondents so that they could make an informed choice regarding participation. The participants were also informed that no personal information would be included within the data collection process or utilised within this study. This is confirmed by the fact that anonymous identifiers have been used for the interviewees. Finally, for data protection purposes, all data collected was gathered personally by the researcher, and recorded and stored on his personal password protected computer.

## 3.7: Limitations

The main challenge of this research approach was to gather recent information on EE’s and ESMCP’s progress towards ensuring the ESN service is ‘at least as good as’ the incumbent system. The latest, detailed information supplied by EE and ESMCP on their progress was in March of 2016. It is understandable that, post the critical analysis of ESN rollout in the September NAO report and the negative PR surrounding it, that EE and ESMCP would be hesitant to go on-the-record and make definitive statements as to what level of service they would be able to achieve, by when. Although information related to EEs proposed solutions to the challenges were available, the researcher was not able to find any extensive published material by EE or ESMCP on their progress post the NAO report and the researcher found it difficult to source EE or ESMCP personnel who were willing to discuss the progress and plans related to the new ESN system. This issue, together with the technical complexity of the systems being investigated, was the reason why the number of participants in the primary data collection process was relatively low.

## 3.8: Summary

In summary, while it was challenging to find current (as of 2017) information on the latest plans for and progress towards ensuring ESN is ‘at least as good as’ the incumbent Airwave system, the research methodology used leveraged the best published information and expanded on it with insights from key stakeholders to develop the most in depth, structured analysis of ESN as compared to Airwave developed to date. To support the outcome of the secondary data investigation into the research aims and objectives, the in-depth perceptions and opinions of individual stakeholders who have intimate knowledge of the issues related to ESN systems and operations were also sought and examined through the primary data collection processes. The outcome from the analysis of the data is presented and discussed in the following chapters (4 and 5).

# Chapter 4: Data analysis findings

## 4.1 Introduction

 Based on the date analysis process presented in the previous chapter, several themes were identified as being related to the concerns identified within the study aims and objectives. In this chapter, section 4.2 provides an overview of the themes identified from the data as these relate to current concerns about the transition to the proposed new EE ESN system. Section 4.2 discusses the outcome of the study

## 4.2: Findings

 Based on the data outcome, it was indicated that in an ideal environment, theoretically the concept of the new ESN should provide positive benefits within the context of emergency services communications. This was confirmed by survey participant 10, who stated, “*ESN ‘should’ provide a modern platform, which will allow 3ES to develop a more coherent IT/Mobile working strategy to achieve broad aims of increasing efficiency / managing costs. Each service has very different needs – so advantage/benefits are different for each service. For police voice is a key need with data less established, so ESN provides a platform to build. For health, they are crying out for data and use voice less, so provides a secure and interoperable platform (and avoids them going their own route for data). For fire, it provides a secure broadband platform for delivery of info on a dispatch – but of little use at fire scene to individual officers.”* Another respondent also mentioned the system’s ‘future proof’ benefits.

However, notwithstanding the positive future benefits, the findings of the survey and interview data identified six main areas of concerns that need to be addressed for the ESN network, provided by EE, to be able to achieve the robust level of service required within the current roll-out timeframe. The proposed solutions presented by EE, together with the findings related to these themes, which consist of coverage, capacity, risk reduction, technology, system testing, and customer engagement, which are based on responses to the solutions presented by EE, are discussed within the following subsections:

### 4.2.1 Coverage

 The main finding noted within the research was related to coverage. The concerns raised in this respect related the following key factors:

#### 4.2.1.1 Remote and rural areas and their backhaul facilities

 EE’s proposal to ensure the ESN cellular system coverage will be increased from 74% to at least 97% to match the current TETRA model (Home Office 2015), and provide effective backup (backhaul) systems using a range of solutions. In addition to government funding for an additional 250 BTS sites (Atkinson 2016), these include increasing the number of ‘Airmast’ sites, portable masts held in positions blimps and drones and, for backhaul purposes, small cells with satellite backhaul. However, the research findings have identified several factors that could have an adverse impact on these proposed solutions, which can be summarised as:

A) Coverage

* Airmast technology (via blimps and drones) is new and still being tested
* Adverse weather, which is more likely in the Northern regions, which would benefit most from this technology, could affect the coverage / QOS provided by Airmasts. Better algorithms are needed to cope with high wind speeds.
* The coverage and QOS of these solutions is limited by their battery life. For example, the coverage balloons EE are trialling have a maximum of 30 days flying time.
* At the TIP Summit, EE also noted that drones and balloons do not have high endurance.
* Balloons and drones require a human interface. Drones in particular, require skilled certified pilots to provide coverage, especially in built up areas.
* There is also the security of the actual site where the new technology will be placed as well as the time taken to replace/ fix in the event of the equipment getting broken or lost/stolen

B) Backhaul

* Temporary VSAT deployments are costly and therefore likely suitable for emergency use only. They can also have latency issues. Additionally trained personal would need to setup the equipment. In some cases this set up would need to happen in secure areas, thus adding to cost and potential longer timescales, which in crucial communications downtime is not an option.
* While Airwave already has infrastructure in place by way of PTP and fixed wire copper and fibre, EE needs to find a site that provides the best area for coverage, set up a leasing contract, planning permission, a backhaul solution and then build the site. This can be both a costly and time consuming process, especially in areas of natural beauty and hard to reach areas, i.e. the highlands of Scotland.
* Latency issues: EE’s backhaul solution is not clear in many rural areas because there is no EE network in place. It is hard to make a comparison if there is nothing available for comparison purposes. Latency issues tested in a lab are very different to those tested in field. Latency is especially prominent when firearms are in use. Liam Maxwell the technical expert for ESMCP eluded to this in the Select Committee Meeting in November 2016.

#### 4.2.1.2 London underground, maritime coverage and air-to-ground coverage

**London underground**

ESMCP’s Whatson confirmed that coverage to LUL underground stations would be provided either via a 4G card in Wi-Fi access points or via deploying a separate 4G base station alongside them with coverage out to the road to make it a seamless part of the EE network (Atkinson 2016). The plans are also to use the existing Leaky feeder cable within the tunnels, therefore connecting into the LUL Connect 2000 system due to space issues within the tunnels. The findings indicate that to achieve these objectives to be considered:

* EE will have to again agreement from TfL before they can implement any new technologies in LUL. Currently EE are in dispute with TfL over how the technology upgrades should be funded, with TfL wanting a share of any future revenue from public use of this service (Williams 2016). In Select Committee Meeting in November 2016, the answer from Simon Frumkin off EE was that talks were in progress and they were confident on terms being agreed.
* Installing new technology within the LUL is restricted to very specific hours (e.g., 1-4am) which will influence the speed of any roll-out once terms are agreed.
* EE will likely need a dedicated LUL team, given that the personal installing and servicing the LUL underground technology need various TfL certifications and training.
* Currently TfL staff have Airwave-enabled mobile phones to report incidents. New 4G enabled devices will need to be fitted in the LUL and TfL personnel will need to be trained on the new ESN system with possible cross-training as they may be using the proprietary system Wave 7000.

**Maritime coverage**

 EE is exploring mesh network techniques to enhance 4G maritime coverage (Atkinson 2016). As of March 2016, EE was experimenting with connecting the 43 ferries that sail between the Scottish Islands via deploying small cell solutions on the ferries, which then mesh to small cells which EE, were positioning on surrounding lighthouses with power. Furthermore, by leveraging existing infrastructure, like lighthouses and ferries, as a base for small cells, EE hopes to bring 4G services to maritime environments where it would be cost prohibitive to deploy large, traditional 4G base stations. However, the findings indicated that:

* Ferries do not sail in high winds and most do not sail throughout the night.
* Some lighthouses can be hard to access and any equipment installed on lighthouses would need to be gale and storm proof.
* The NAO (2016) report in highlighted the high risks associated with deploying new technologies, such as mesh network technologies, under the aggressive timelines set for the ESN.
* Emergency service personal are aware of the NAO report and will be hesitant to take up ESN until the service is deemed to be without risk

**Air-to-ground coverage**

ESMCP’s Whatson provided a small number of details regarding their A2G solution at the March 2016 BAPCO event, which was comprised of using TDD (Time Division Duplex) spectrum. A Prior Information Notice (PIN) (Secretary of state for the Home Office 2016) published in September 2016 states that the Home Office are now pursuing an A2G solution, which uses both current Airwave TETRA technology and 4G technology. The PIN outlines that the current plan is to use the TETRA system above 500 feet to communicate with emergency service aircraft and to use the EE ESN network below 500 feet. The findings indicated the following considerations need to be considered:

* The combined Airwave and EE solution should ensure adequate A2G coverage for the emergency services and allow the time needed for LTE to evolve to a point where full A2G coverage can be provided via a 4G network
* The Prior Information Notice (PIN) states: ‘The Project is currently working with user organisations and further developing its requirements. As part of this process, industry engagement is required to refine certain technical points. The Home Office is therefore issuing an RFI Questionnaire in late 2016 and will be hosting a supplier briefing event accordingly.
* The PIN also stats that the ‘standalone procurement of A2G devices may or may not include separate lots within it’ (Wireless Magazine 2016).

*4.2.1.3 Indoor (enclosed areas)*

At the March 2016 BAPCO event, EE outlined that they had 4G small cells and DAS solutions ready ‘to pull the trigger on’ but did not provide definitive answers on whether this system would be using routers or another technology to ensure proper integration into the macro network.

 The researcher could not find enough information on the subject of in-building solutions and small cells. While in-buidling was mentioned during the Select committee sessions towards the end of last year, these references are probably with regards to current customers on the EE Network using their phones in the home, whilst still attached to the network. .

*4.2.1.4 Major events coverage*

EE did not specifically outline its plans for handling major events at the March 2016 BAPCO event, thus questions remain regarding how the ESN will handle these situations. However, the findings from the research and discussion concluded that:

* Like Airwave, EE will explore shifting capacity from an under used area (e.g., a rural area) in order to service the coverage needs of a major event like Notting Hill Carnival, and will explore the use of Airmasts along with meshed small cells to provide additional coverage for major events where adverse weather is not an issue
* Additionally software and standards for giving the emergency services network priority already exist. EE have also said they are building out their infrastructure to cope with the many power cuts in the country
* New software and hardware solutions (from software upgrades though to technologies to deploy Airmasts and batteries) still need to be deployed and tested to ensure they work flawlessly during mission critical events
* Once Test and Assurance has taken place, EE can then carry out a RAN audit in-order to optimise its network to provide a service “As Good” as the incumbent Airwave

### 4.2.2 Capacity

EE have confirmed they are building in extra layers for capacity and leveraging new technologies, such as carrier aggregation (CA), where disparate bits of spectrum are combined to provide more throughput capacity to meet traffic demands, to ensure they have the needed capacity to handle the needs of the ESN (Atkinson 2016). EE are also upgrading thousands of sites to the 800MHz spectrum, which the MNO won in 2013 (Ofcom 2013). The advantage of 800MHz is that it propagates over longer distances and is better at penetrating buildings. EE also confirmed in March of 2016 that voice over LTE (VoLTE) was beginning to be switched on, with the promise of dropped call rates of below 0.2 (Atkinson 2016). Based on the findings, the following concerns were highlighted in this respect:

* While the 800MHz spectrum carries better penetration than other parts of spectrum EE owns, the 800MHz spectrum is known to have interference issues which could cause quality of service problems
* The 800MHz portion of the spectrum also suffers from low capacity issues, which could be particularly problematic for the streaming of HD content (that said the fact that ES personnel will be able to stream HD content at all is an improvement on the existing Airwave system).
* Concerning CA, not all classes of mobile phones (and likely not all handsets) support CA.
* While CA is used in LTE-A to increase Bandwidth and capacity, the process of getting to eNB can reduce throughput

### 4.2.3 Risk reduction

 Risk reduction is related to the extent to which risk reduction is achieved. In March of 2016 (Atkinson 2016), EE reported it was deploying a range of solutions including battery backup, fixed and mobile generators, resilient transmission, flood defences and rapid response vehicles. Concerning transmission resilience, EE stated they were implementing ‘multiple routes back to the network to connect every base station to the core network’. These paths would be made up of wireless links, satellite and leased lines. EE also confirmed they were exploring how Airmasts could be used in emergency situations. However, the participants and other research indicated that:

* Any batteries or generators which EE deploy will need to be maintained by employees (from EE or from another service provider) who are electrical qualified.
* Any BTS’s fitted with batteries will also need air conditioning to ensure the batteries do not swell from overheating
* The limited life-span of batteries makes them a less practical solution for sites which have limited access
* Fixed line backhaul can suffer from water penetration and extreme cold as well as delays from fixed line provider to fix any issues in a timely manner.
* Point to Point does not always have resilience built in, if resilience were a major factor then EE could possibly employ a GBNR

### 4.2.4 Technology

 In terms of technology, three main factors have been examined within the research and data analysis, which comprised of a) direct mode operations, b) software, and c) mission critical standards for LTE.

A) Direct mode operations

EE have already conceded that DMO might not be in handsets by the time emergency service network users start transitioning to ESN and that back-up plans will likely be needed (Atkinson 2016). One of the alternate options being considered as of March 2016 was that of dual-mode devices, which would harness both TETRA and LTE. Nonetheless, the following concerns were indicated within the findings:

* P3 ProSe are still testing hence a standard specification has yet to be set and it is unlikely that there will be a standard with REl12.
* Currently the situation is hard to compare as no operational testing has been carried out within 3ES.
* EE would most likely need a business case to create a DMO service that negates the use of MNO networks. Perhaps this would only be available on the 3Es network

B) Software

ESN is required to match the level of service provided by Airwave. That level of service will need to include an ESN talk group identical to an existing Airwave Talk group, interoperability between Airwave and ESN and interoperability between various agencies. For example, policemen will need to be able to communicate with ambulance crews even if each organisation is at different stages of the transition to ESN. Transition programmes will thus need to include functionality which ensures control rooms can use different gateways simultaneously. Gordon Shipley’s July 2016 Home Office Spectrum Policy Forum briefing (Shipley 2016) on ESMCP identified three main details on the software to be used for control room upgrades, which indicated 1) that Motorola will provide the software upgrade and test, 2) Interoperability will be delivered using Wave 7000, and 3) that the control room will be connected using a DNSP from PSN. The findings from the data raised for following concerns in relation to the software issues:

* It is not yet clear if ICCS will still be the software used by dispatchers in the control
* If not, an ample amount of time will need to be allocated to train despatchers on how to use the new software/hardware

### 4.2.5 System testing

The testing concerns considered were related to two factors, a) end users, and b) device testing.

A) End users

EE’s test plans include drive testing, an app-based solution (which they note would only measure where the end users actually go) and geo-location statistics from the network which would then be triangulated. However, to facilitate this testing situation, the findings highlighted the following factors:

* As there are many agencies involved in the rollout of ESN, roles and responsibilities with regards to testing should be clarified, possibly via a RASCI model (which highlights who is Responsible (R) for owning the testing, who is Accountable (A) for sign off of the testing, who are the Supporters (S) providing resources in implementing the testing, who are the testing Consultants (C), with the information and capability to complete the work and who must be Informed (I) of the testing results.
* As per the NAO (2016) report, ESN would also benefit from independent testing, beyond that of EE personnel.

B) Device testing

 The mobile devices selected for communication over the ESN network need to be effective and easy to use by emergency services personnel, in other words fit for purpose. The NAO (2016) report stated that the programme was aiming to have devices selected by the end of 2016, however, as of April 2017 devices have yet to be selected. Before the businesses can bid for the contract for handsets, they need to have already gone through a process NATS to prove the handsets are capable of working in 3ES operational environment, and also First Rel12 will need to have MCPTT. The main issues raised in the findings concerning device testing were the following:

* Testing and Assurance in all released Releases.
* Training
* Talking on handset whilst driving (e.g., will there be Bluetooth functionality to enable safe and legal use)
* Capable of multi affiliations with a given talk group
* Capable of DMO
* Air to Ground
* Security, especially with Wi-Fi and Bluetooth turned on.

### 4.2.6 Customer engagement

 It is apparent that customer engagement with the current TETRA system is good. However, the question that needs to be considered is how EE will respond when issues begin to arise in the new system, as the corporation will have total responsibility for MCPT**T** following the changeover. The findings from the data have indicated that those responsible for the ESN need to continue to progress with the selection of the handheld devices emergency service personnel will use, and in this respect, indicated that the following should be considered:

* Choose a handheld that has passed the NATS testing process from a supplier that has also been successful with the procurements requirements stated within the Home Office brief. As stated in Commons Select Committee by Mr Webb the SRO, they are looking to provide a robust handheld that will have the capability to use Wave technology, be able to PTT, albeit on Rel 12.

## 4.3 Summary

 The outcome of the analysis of the research data presented within this chapter has confirmed that there are a number of complex issues that need to be addressed during the remainder of the ESN transitional period if the changeover to the new system is to be of the required operational quality and completed within the projected timescale. The following chapter discusses these findings in more depth in the context of a comparison of the existing TETRA system and the existing research that has been focused on this particular ESN system.

# Chapter 5: Findings analysis and discussion

## 5.1 Introduction

 The findings presented in chapter 4 are further analysed and discussed within this chapter. To provide a framework for this purpose, the first section presents a brief overview of the existing TETRA system for comparative purposes (5.2). Section 5.3 then discusses the findings in the context of the literature. This is followed by a discussion related to how the findings presented are perceived to affect the completion of the system changeover within the contract prescribed timescale and consideration of potential cost consequence of any delay.

## 5.2 Existing system comparatives

The following table (2), serves to identify the current and capabilities in relation to the themes discussed from the data analysis, which has been compiled from information available from the organisation website together with the observations from the participants who contributed to the primary data collection process.

Table Existing TETRA model capabilities

|  |  |  |
| --- | --- | --- |
| **Theme** | **Sub-theme** | **Capabilities** |
| **Coverage** | Remote/Rural areas | Infrastructure: The Airwave network has approximately 4,000 BTS’s, with a mix of Co-Linear and Omni Directional and Macro Antenna, there is also a mix Sectored and Non-Sectored. Many of these BTS’s have back-up generators on site (Atkinson 2016) with fuel for seven days of autonomous running in an event where the main power is cut, along with a range of resilient backhaul solutions.Overall Coverage: This infrastructure has allowed Airwave to achieve approximately 97% coverage of the UK. |
|  | Backhaul | Continuity: The airwave Network delivers continuous, high performance communications via a VSAT (Very Small Aperture Terminal) network (DataSat Communications 2014), which covers the most remote locations in the UK, including the Islands of Scotland, Wales, Cumbria and North Yorkshire. This VSAT network is also used for the rapid deployment of mobile terminals in the event that a base station fails or when a natural disaster temporarily removes terrestrial connectivity. The system is comprised of connecting a VSAT modem and antenna to a Tetra base station at the distant end. This backhauls network traffic to a teleport and onto the airwave Network to deliver continuous communications |
| London underground | Coverage: Airwave's network coverage extends to all 125 London Underground (LUL) and below ground stations (Airwave 2017) and is facilitated via leaky feeder coverage in the tunnels connected to Airwave Tetra base stations or Enhancers/Repeaters.The leaky feeder is one cable that runs throughout the tunnels. MNO plug into the Connect 2000 equipment within a secure part of London Underground. |
| Maritime coverage | Coverage: Airwave currently supply maritime coverage up to 12 nautical miles |
| Air to Ground  | Coverage: Airwave currently supplies A2G coverage up to 6,000 feet |
| **Indoor/Closed area** |  | Coverage: The Airwave Tetra network currently provides coverage inside buildings through a variety of solutions, including off-air repeaters and Distributed Antenna Systems (DAS). Enhancers are used, which essentially enhance a signal from the local BTS. However, this can be tricky if the radio within the building connects to in IBS and then radio re-selects for the stronger local signal, if by a window for instance.  |
| **Major events** |  | Flexibility: Under the Airwave Tetra system, major events have often been serviced by reconfiguring specific sections of the network. These reconfigurations can include adding more users to a single base station and shutting off channels in areas where the network is less urgently required (e.g. rural areas) to free spectrum and provide more capacity in city centres. Customisation: Airwave has also built private mobile networks (PMRs) for certain major events. .For example, Airwave, built a dedicated PMR network, called Apollo, to support the 2012 Games. The Apollo network ensured secure communications for more than 18 000 officials and volunteers during the games. Prioritisation: Because the Airwave Tetra system is a dedicated network, emergency communications are, by default, prioritized and not competing with those from the public |
| **Capacity** |  | Prioritisation: Because the Airwave Tetra system is a dedicated network, emergency communications are, by default, prioritized and not competing with those from the public, which is especially important during major events when public usage of mobile networks is likely to surge.Flexibility: When there is potential for capacity issues during a major event, Airwave are able to reconfigure specific sections of the Tetra network, including re-channelling spectrum from one area to another, to add capacity to an effected/key area.  |
| **Risk reduction** |  | Autonomous power capabilities: Airwave has back-up generators at their 4,000 BTS’s to keep the network running for seven days in case of a power cut. Portable generators: Airwave have dedicated field engineers who carry portable generators and can deploy mobile base sites 24/7 as neededMirrored switching centres: Airwave have mirrored switching centres which are capable of moving from primary to secondary in under two minutesFall-back: The Airwave system has fall-back capabilities in the event of a system failure to any of the primary switch clusters within the network |
| **Technology** | Direct mode | DMO within the AW network works even when there is no network available, not dissimilar to a standard walkie-talkie.DMO is also used within the Gateway system, which essentially allows the user coverage from G/W equipment installed around low or possibly incidental coverage. After speaking to many officers in the field, most have never used or needed to use DMO. Specialist units however do use DMO.  |
|  | Software | Fully tested and proven software capabilities, with significant training having been provided to user personnel |
| Mission critical | In addition to coverage, capacity, resilience, security and proximity services, the Airwave Tetra network delivers Mission Critical communications via:* being a dedicated network (because Airwave is a private network, emergency communications are, by default, prioritized and not competing with those from the public)
* providing ‘push-to-talk’ (PTT) and ‘group-call’ functionality
 |
| **System testing** | End users | When Airwave was launched, it was required to test-drive the network, testing the voice quality and signal strength approximately every 25 metres. The Airwave network was also tested via walk-testing in pedestrian areas and key indoor areas, including police stations, shopping malls, hospitals and government buildings. The above testing process has been repeated throughout the life of Airways after periods of maintenance, as frequencies have been retuned and during site issues.  |
|  | Device testing | The current Motorola handsets which are Sepuras and Motorola MTH800 in use for the Tetra system are generally very robust, waterproof, and enable Group call to many and PSTN which is important for the emergency services networkThese handsets are fully encrypted and in use for the 3ES and its PartnersMost partners are trained on the equipment and inter-operable with 3ES and partners through specific talk groups |
| **Customer engagement** |  | A solid background of operational effectiveness and efficiency with the Emergency Services |
|  |  |  |

## 5.3 Discussion of the findings

 As indicated in chapter 4, the findings presented were focused on the key factors that coincide with the table (2) presented in the previous section of this chapter.

 Concerning coverage, the general consensus of the interviewee respondents coincided with the view that had previously been expressed in the literature, namely that the EE ESN proposed system currently was significantly lower that the target of 97% that was required by the time of the changeover (Parliament 2017). Indeed, INT 2 indicated that, at the current rate of progress, particularly due to the issues related to remote, underground, indoor coverage, while it was likely that the coverage level would eventually reach the target, even with government financial assistance, he doubted whether this could be achieved within the timescale set.

 Equally, concerns were raised over the effectiveness of the system, as it is currently designed, in relation to major events and capacity. Specifically in this respect, one of the concerns raised was related to the fact that the ESN system is being operated using a public platform (Yarwood 2010; Loukas et al 2013). INT 1 commented, “*When you have a system operating on a public platform two main issues can occur in my view. The first of these is that the system itself can become overloaded with data traffic and outage problems, which will interrupt the ESN communication, thus increasing the risk. The second is the potential for security breaches, which will similarly add to risk. The issues are important to address, especially when one is dealing with such a mission critical programme.”* These findings in relation to risk reduction and mission critical aspects of the ESN system concur with the views express in the literature (Sterle et al 2015; Schulzrinne and Tshofenig 2013; Cole and Hawker 2014). Grey et al (2011), also commented on mission critical aspects in relation to the transitional period, arguing that in their view critical communication should support intra-systems handovers from the existing TETRA, and that they do not expect to see critical communications voice services carried over LTE bearer for the time being because PMR systems must fulfil the pre-set critical requirements.

 System testing and user training were other issues raised by the respondents. Concerning system testing, INT 2 stated, “*It is difficult at this stage to identify the extent to which the system devices are capable of fulfilling their purpose as these devices have not yet been fully tested. One of the other issues related to this is that until this testing is completed and they are pronounced ‘fit for purpose’, it is actually impractical to commence the training programmes”.* INT 5 commented, “*The difficulty with testing and training is timescale. While to a limited extent there may be a small degree of overlap, generally the training will follow on from the testing programme, thus they are time consuming elements of the programme development”*. The report by presented to Parliament (2017) confirmed that testing and training should be completed within the contract timescale, but were concerned about whether this would happen, particularly given the five month delay notified.

Finally, within the area of customer engagement, it is apparent from the comments presented within the survey questionnaire, that there is a significant lack of trust emanating from all the stakeholders, particularly those employed within the emergency services that the ESN will be able to deliver a product that is fit for purposes. Consequently, many of the respondents argued that they had no intention to change-over the new system until they were 100% confident of the quality and capability to provide a service that was at least a standard that matched the current system. Support for this view can be found in a statement issued by the police officers federation, which stated that, “*Lives are at stake if we get this wrong and this is an area where the PFEW will simply not accept a replacement service that is inferior to what we already have. Cost savings should not be put before the safety of any police officer or member of the public”* (Police Federation 2017: 2)*.*

## 5.4 Completion timescale

 It is apparent from the responses of the interviewees that the completion timescale initially set for the transition from the current Airwave TETRA system to EE’s cellular was, as INT 3 stated “*ambitious to put it mildly”*. INT 5 went further in this respect, arguing that consecutive UK governments should have enough experience from previous technology project failures to “*know that A) it is essential to invest the time to devote to intensive research by experts in the field so that they can positively identify and address the potential problems and b) add the R&D process time to the front end of the contract period, rather than expect it to be robustly performed during the limited time of the transitional period, which is a recipe for disaster.”* In this respect, the findings concur with the comments may by the industry expert, Peter Neyroud, who argued that from the moment the contract was developed and awarded to EE it should have been apparent to all parties that “*the [ESN] completion date was never do-able”* (Hall 2016).

Indeed, this has been proven to be the case as the NAO (2016) has already confirmed that a five month delay in the project has already occurred. Moreover, although the stakeholders involved in the contract, the government and EE, have suggested that they had set in place strategies that would allow this delay to be recovered during the remaining period of the contract, recent media reports have suggested not only that an additional delay of another 6-9 months has occurred, but also that the government has agreed to extend the completion date to account for this addition period. However, to date, there is no indication of the financial cost of this extension, although based on the research it is likely to be around £400 million (Williams 2015). Perhaps of equal importance is the fact that delays of this nature are likely to undermine the trust and confidence of the emergency services personnel, which in turn could delay their decision to transition to the ESN system, adding additional costs, and therefore, further diminish the financial benefits the change was intended to provide.

## 5.5 Summary

 The discussion of the findings presented in this chapter have confirmed that there are several issues that need to be addressed prior to the change-over from the current TETRA system to the new ESN system operated by EE being considered a) fit for purpose a b) of a sufficient level of quality and robustness that will seamlessly replace the existing Airwave model. Of significant important in this respect is not only the potential damaging cost of the reluctance of emergency services to implement this system across their organisations, and the cost to the taxpayer resulting from the delay in the completion timescale, but also the human cost that the failure of the system is likely to cause, which will be unacceptable to the public the emergency services are morally responsible to serve. Taking these factors into account, the following concluding chapter of this study, in addition to identifying the extent to which these findings have supported the research hypothesis set in the introduction chapter, also identifies and discusses the implications that these findings have on the stakeholders involved with the new cellular ESN system.

# Chapter 6: Conclusion and recommendations

## 6.1 Introduction

 The research process presented and discussed in this this study were designed to provide a further understanding of the challenges being faced in relation to delivering the EE ESN system within the proposed timescale, and to chapters were designed to deliver an appropriate understanding and response to the hypotheses set for the study, which were:

Hypothesis 1: *Given the current maturity of 4G technology and the current status EE’s 4G network, further work and validation is needed to ensure the EE ESN service is ‘at least as good as’ the incumbent Airwave solution.*

Hypothesis 2: *There is a need to extend the current TETRA system beyond the 2019 deadline to ensure the continued quality of the emergency services communication while 4G technology matures and EE puts in place and test solutions to the point where emergency service personnel are confident that the ESN service is indeed as good as the incumbent Airwave solution.*

It is apparent from the literature and reports from government departments, and other external organisation and experts that there are a number of concerns related to the ability of EE to meet the challenges identified in hypothesis 1. However, although, as is shown in chapter 4, EE has presented a number of potential solutions that are designed to address these challenges within the pre-determined timescale, the findings from the research conducted for the current study, have raised concerns regarding the efficacy of these solutions and the ability to implement them within the designated timefram, the outcome of which tends to support hypothesis 2.

## 6.2:      Implications of the findings

It is apparent from the findings that the outcome of the research has a number of implications for the stakeholders involved in the ESN transition, specifically those involved in the original contract decision process and in the delivery of the end product (system). In this respect, based on the outcome of the findings of current study, it is argued that the findings will have the following implications for these stakeholders:

1. It will increase programme costs of the ESMP, which will minimise cost savings, and will infringe on the original austerity request from the Government to save money, which was one of the main governmental requirements and objectives to be embedded within the project.
2. If EE cannot deliver the quality of the product/programme they agreed to on signing of the original contract with the government, and any subsequent caveats agreed, then potentially it could be subjected to contracted penalties, which may considerably reduce the level of profitability they were anticipating.
3. Delay to the ESN rollout will also incur additional funding from the Government to Airwave. The Government are negotiating terms for a month by month, region by region. However, notice of at least a year will be required due to the constraints of the Airwave current contracts, which will need to be re-negotiated as their tenure was due to finish in 2020.
4. To ensure the quality of the service provided by the emergency services and reduce the risk to the public, it will be essential for the government to keep the Airwave system running in tandem with the new ESN, until such time there are proven assurances that the ESN will be able to work to the same levels of service as that of Airwave network.

## 6.3:      Recommendations

            The researcher also feels the Home Office and industry experts need to re-examine how critical radio is defined, and especially as technology evolves. While EE needs to be more robust and provide mission critical communications, the researcher feels it is not entirely fair or pragmatic to measure ESN offering against that of Airwave. By stating the ESN must be “at least as good as” Airwave, means ESN must work to the same strength of the incumbent, which is a completely different sort of PMR radio, versus a network that provides 2G, 3G and LTE to the public. It is important that stakeholders should recognised the unique advantage of ESN such as Data/Broadband capabilities, future cost savings and benefits which will emerge as technology continues to advance. The UK is rolling out a Mission Critical network, which is deemed very high risk, as this approach has never been done before anywhere else in the world.

Good early flow on information and kept informed on network plans from EE and the project leaders ESMCP, this will demonstrate that the project is achieving the milestones and possibly convince the wider public safety community that the project is implementing the core mission critical standards which is resilient and reliable, and stands up to the network coverage required by all 3ES. These views were echoed by Mr Richard Bacon in the Public Accounts Committee in November 2016. I also believe it would be favourable to have a space where all major updates and changes to the programme could be stored; this again would demonstrate that the programme is aware of any problems and could be an area where industry experts give their opinion on any ongoing issues within the network.

A fully comprehensive test and assurance plan for RF Coverage and capacity within the UK. Within the Public account committee, Stephen Webb on the ESMCP Home Office stated that the testing could not to disrupt the network as the EE still have its users connected to the live system, and that testing a cellular network is quite different to the testing that was completed for Airwave. He hinted at devices that where in vehicles that would monitor the areas the vehicles drove through and crowd testing, essentially using the public who are already on the network. In January, the Government issued an RFI for third party companies to bid for the role of testing the network and providing assurance, the selected companies are yet to be announced. An important part of the testing is voice testing (VQ), devices that sit in a vehicle and monitor the network will not necessarily measure how good the VQ is within these areas driven, and you can never presume because there is reasonable coverage and capacity that the VQ is going to be good.

Given the number of areas where ESN do not have a complete coverage solution, (e.g. A-2-G and the London Underground) as well as the number of areas where EE’s solution is not fully rolled out and tested, there is a need to keep the Airways system running in tandem with ESN for the foreseeable future. This will require the re-negotiation of contracts with Airwave given that the current contracts are due to expire at the end of 2019. Efforts should be made to explore how to put a solution in place, which leverages specific regions of the Airwave network (e.g., London) and enables other regions of the network to switch over to ESN, thus reducing the overall incremental cost of the project. During the public accounts committee, these points where brought up by the Permeant secretary Mr Sedwill and the SRO Mr Webb, suggested that if any of the 12 regions felt that they could transition across to the ESN, obviously after being fully tested and assured then that part of Airwave could be possibly turned off, hence the statement that Airwave could charge per region, per month. Even whilst preparing this dissertation, a report has been published by the public accounts committee that suggest this situation is likely to arise.

## 6.4:      Future research

 It is apparent that any academic study of this nature will have areas of limitation, the addressing of which may require future research. In this particular case, it is considered that the limitations relate to two main areas, namely the size of the sample population and the fact that the research has been focused on an examination of the robustness of the new ESN system and its potential readiness to for the implementation within the pre-determined time scale, at a set point in time, this being early 2017.

 In terms of future research, in many respect these two issues are interconnected. For example, as the ESN system remains in the early stages of its development and implementation process, the number of user available to provide responses to their experiences from testing the new system available remains limited at this point in time. Equally, as noted the content of the current study is time constrained, providing a snap-shop of the position of preparedness of the new ESN system at this moment in time.

 Therefore, based on these limitations, it is recommended that there is a need future research studies to be conducted at regular intervals during the remainder of transitional and implementation period, as many changes are likely to occur during the next three years. The objective of these studies be a) to include a wider range of stakeholder perceptions and experience during the testing period, b) to identify the extent to which, if any, the potential delays to the live date of the new cellular ESN beyond the current 5 months identified in this study, and the potential financial costs of these further delay, particularly in terms of continuing the current Airwave contract. Specifically, within the context of this future research, it is suggested that the following key questions should be considered:

* As the data will essentially be in the public domain, who has access and can the data be sold on. For instance, Insurance companies may find data emergency ambulance journeys or persons detained due to drunk and disorderly behaviour without charge to be relevant in relation to the insurance cover and premiums they offer to these and other stakeholders with these groups.
* Is MCPTT working on a 3GPP Standard?
* To what extent has the coverage for EE been extended to areas where there is currently no service?
* Has the issue of resilience been addressed in that, if a site is subjected to high winds or a power cut, will the Airmast, or alternative options (blimps and drones) battery/generator be efficient enough to keep a site on air until an engineer resolve the issue?
* To which extent have the backhaul (back-up) solutions been incorporated, and have fibre or satellite communications with resilience been built in to these solutions in case of failure?
* Would it be necessary to remove customers off an EE cell, in-order to create more capacity specific urban areas, such as London?
* Is there inter-operability with all 3ES radios?
* Does the underground have a full LTE solution?

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# Appendix 1: Survey questions





# Appendix 2: Survey responses









