ENSURING RESILIENT TELECOMMUNICATIONS:

A SURVEY OF SOME TECHNICAL SOLUTIONS

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Civil Contingencies Secretariat

Contents

Background to this guidance

1. One of the key issues identified in the aftermath of the 7 July London bombings was the vast increase in calls on the fixed and mobile telecommunications networks. Demand for use of the GSM network (see para 14) greatly exceeded capacity and callers experienced difficulty in making and receiving calls for a few hours after the explosions. This exposed shortfalls in the arrangements for a number of responders requiring **resilient communications**. Although July 7 highlighted issues surrounding GSM-based communications, severe degradation or failure of telecommunications have been cited as a major concern underlying the response to many incidents including: the flooding in Boscastle (August, 2004) and Carlisle (January, 2005), and in the USA following hurricane Katrina (August, 2005).

2. In March 2006 we issued guidance on resilient telecommunications (reference 11) to Regional Resilience Teams for cascade to Category 1 responders under the Civil Contingencies Act.

3. This document provides greater insights into the resilience of the technical solutions identified in the earlier guidance. This guidance is intended to assist those seeking to enhance the resilience of their telecommunications by identifying potential technical solutions and providing sufficient background to enable the resilience issues to be explored with potential service providers.

How to use this Guidance

4. Hyperlinks have been used extensively throughout this guidance. Text in blue is hyperlinked: click the text to follow the link and use the key combination "alt + left arrow" to return to the jump off point. The Guidance has also been formatted for printing.

Ensuring resilient telecommunications

Resilience

5. There is no silver bullet to achieving resilient telecommunications and different responders are likely to achieve resilience through different means. Resilience should be driven by the need to communicate and not led by the availability of technical solutions.

6. Resilience is enhanced though a careful consideration of three inter-related issues:

(1) way in which a **response to an emergency is organised**,
(2) **processes used for communicating** and
(3) **characteristics of technical solutions used to communicate**.

7. Drawing from experience, and from risk assessment work, we believe that the planning assumptions in reference 10, adapted as necessary to local circumstances, should be used as the framework for testing the resilience of responder communications. The National Infrastructure Security co-ordination Centre (NISCC) publish helpful additional guidance on resilience of telecommunications systems (at reference 1) and information relevant to contracting services (at reference 12).

Guiding principles

8. **Not relying on a single technical solution** (such as GSM networks (see para 14)) and adopting a diverse, layered fall-back approach to communications can go a long way to enhancing resilience. A layered fall-back approach recognises that no means of communication is always likely to be available. In the event of failure or unacceptable degradation of the primary means of communicating, falling back to another option (possibly providing less 'rich' communications*)* helps absorb disruptive challenges or mitigate their effects. Fall-back options are likely to require a reconsideration of the inter-related issues identified above (at para 6).

9. **Technical interoperability** is often taken for granted with 'gateways' between different telecommunications platforms (such as GSM networks (see para 14) and the PSTN (see para 137)) that provide seamless communications. But this may not always the case, for instance gateways are not necessarily provided to the PSTN from private business radio systems. **Procedural interoperability** becomes increasingly important with point-to-multipoint communications (see para 161). Communication is greatly enhanced through agreed protocols, these can take the form of call-signs and radio discipline (particularly for mobile radio communications (see para 81)) and agreed procedures for managing conference calls.

10. The use of certain **technical solutions solely for contingency use** (for example, satellite systems (see para 123) or radio communications systems (see para 95)) can result in unanticipated consequences that could result in ineffective communications.

Dependency on other communications systems

11. Diversity is a key enabler of resilient telecommunications. However, it can be difficult to assess how truly diverse technical solutions are because of the dependencies of one technical solution on another. Dependency arises in many forms. At a very fundamental level, all public land mobile networks (see para 13) are dependent on core communications networks (see para 133): failure or degradation of core networks may affect mobile services. Pager systems offer diverse means of initiating messages: through a voice call to a bureau, from an SMS (see par 19) sent over a mobile phone or on-line via a website. Each of these means of initiation has its own dependencies, linked to the particular service providers selected as well as the availability of the underlying voice, message or IP network used as the bearer. Diversity issues can be very complex and should be explored with any prospective service provider to a depth that is appropriate for the requirement.

Availability of communications systems

12. Communications systems will not be available 100% of the time. Availability is a consequence of the reliability of the system (associated with faults, including failure of power supplies) and its ability to cope with congestion (resulting from excessive demand). All communications systems are susceptible to congestion when demand exceeds the available capacity. The capacity is usually expressed in terms of bandwidth, number of concurrent calls, or a measure that is proprietary to the technology (such as 'slots' in GSM networks). Systems can be managed to increase the number of concurrent calls through more intensive use of bandwidth, although this is at the expense of reduce voice quality. Communications systems are managed to maintain the maximum number of conversations at an acceptable level of quality. If the traffic on a system were not to be managed the system would become effectively grid-locked and the total number of separate calls would start to decrease. All commercial systems are carefully sized to provide some headroom for periods of high demand. However, headroom comes at a cost and as a consequence substantial headroom is only available where the economics are favourable. Additional guidance on availability of telecommunications systems is provided by the NISCC (see para 158) at reference 1. The availability of a communications system should be explored with any prospective service provider.

Public land mobile networks

Overview

13. The Public land mobile networks, or PLMNs, are the cellular systems over which the following public mobile services are operated:

(1) **GSM** (see para 14), **Global System for Mobile** communication, sometimes referred to as the second generation (or 2G) system.

(2) **GPRS** (see para 32), **General Packet Radio Service** (or G2.5) is a data service run over GSM (see para 33), for this reason, the information assurance issues are covered under GSM.

(3) **UMTS** (see para 45) Universal Mobile Telecommunications System (or 3G) system.

Global System for Mobile

14. GSM voice services (see para 16) and data services (see para 17), excluding cell broadcast (see para 18), are point-to-point (see para 161) services for duplex (see para 166) communication. Cell broadcast is a one-way (see para 159) service. Only the Short Message Service (see para 19) and cell broadcast can be used as point-to-multipoint (see para 160) services, however, in reality this service is transmitted as multiple point-to-point messages.

15. There are four GSM networks: O2, Orange, T-Mobile, and Vodafone. All offer similar services including international roaming. A secondary market exists for services that result in 'virtual service providers', for example Virgin services are provided over the T-Mobile network. GSM networks are now mature and all operators claim 99% coverage of UK population, note that geographic coverage is significantly lower. Geographic coverage can be assessed via the link at reference 9.

Voice services

16. GSM was designed having interoperability with ISDN (see para 137) in mind, and the services provided by GSM are a subset of the standard ISDN services. Voice is the most basic and most important service provided by GSM and operators provide a number of user services such as Voicemail, Call Waiting & Call Hold, Call Forwarding, Call Restrictions, and Show or Hide number. Some operators offer Push-to-talk over Cellular (PoC) services which enable terminals to be used as walkie-talkies: pushing a button enables a conversation to another terminal or group of terminals. Only one person can talk at a time and all other participants listen.

Data services

17. GSM supports a number of data services, called 'bearers', with transmission rates up to 14.4 kb/s per channel over point-to-point (see par 161) connections. Specially equipped terminals can connect with other systems including the PSTN (see para 137) and ISDN (see para 137) delivering services such as Group 3 facsimile, videotex, and teletex. Videotex services are information services that deliver low resolution text. Ceefax (operated by the BBC) and ORACLE (the equivalent independent TV service) are the only surviving commercial services in the UK. Teletex is an international specification for a text and document communications service provided over the PSTN (see para 137). Teletex allowed for the transmission and routing of Group 4 facsimile.

18. Cell broadcast can be used to broadcast messages to terminals in specific cells in a network. This service is particularly useful for information such as traffic reports.

19. Short Message Service, or SMS, is a 'store and forward system' and handles messages in a different manner to wide area paging systems, (see para 76). The implications of this are that if the recipient terminal is unavailable the message is stored by the system for later resend. While most messages are received immediately timing can be unreliable. SMS uses a signalling channel as distinct to dedicated channels, text messages can be sent independently of other services over the network. The signalling channel is less susceptible to congestion.

Data rate

20. GSM was designed for voice services (see para 16) and was optimised for low speed circuit switched data. The original transmission rate of 9.6 kb/s was upgraded to 14.4 kb/s and occupies only a single voice channel. Table 1 provides an indication of the time taken for (error-free) file transfers for files of various applications.

Table 1
Typical GSM download times for typical files

File Type	Approximate size (kilo byte)	Download time @ 9.6 kb/s (second)
A page plain text for example 800 word email	5	4
A page plain text, 800 word “MS Word” document	25	20
Typical internet webpage	50	41
Mobile phone image, 176 x 220 pixels x 18 bit jpg	22	18
160 kb/s MP3 audio file, approximately a 4 minute track	3,800	3,180

Dependency on other systems

21. All networks are dependent on other telecommunications infrastructures not only for calls leaving the parent network but also for calls originating and terminating within the same mobile network. The dependencies arise from the connections between the key elements of the network shown in Figure 1, which are frequently leased lines (see para 146) and generally are not under the direct control of the mobile network operator.

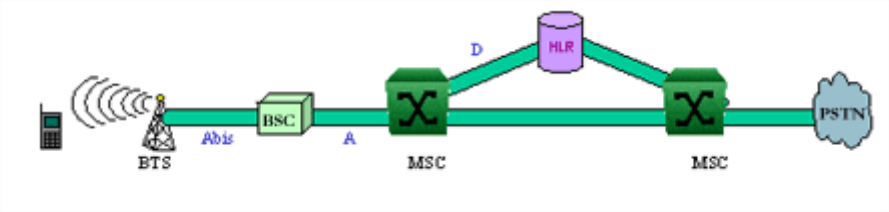

Figure 1. **Simplified architecture of GSM**

22. The key elements of a GSM network are: the **BT plcS** or base station containing the radio transceivers that define a cell or sector; the **BSC,** or Base Station Controller, that manages the radio resources for one or more base stations, handling radio channel setup, frequency hopping, and handovers; the **HLR**, **or** Home Location Register, which maintains the administrative information of each subscriber registered in the network, along with the last known location of the terminal; the **MSC**, or Mobile services Switching Centre, that provides the interconnection to networks such as the ISDN (see para 137) and PSTN (see para 137). In conjunction with the HLR, the MSC provides all the functionality needed to handle subscriber registration, authentication, location updating, handovers, and call routing. The **VLR**, or Visitor Location Register, is typically implemented within the MSC so that the geographical area controlled by the MSC corresponds to that controlled by the VLR. The connection between the MSC and HLR is vital since it is utilised every time a terminal is switched on and attempts to connect to the network, in the establishment of call connections, and in mobility management when a terminal moves between different base stations. Loss or congestion of these connections degrades the service.

Dependency on grid-distributed electricity

23. All networks are dependent on grid-distributed electricity. All network management centres have fall-back electricity supplies. Base stations are generally not provided with back-up generation capacity, however exceptions exist where they are located at facilities

with arrangements for back-up electricity supplies such as hospitals or key telecommunications facilities. At base stations, following a grid-distributed electricity failure battery back-up will typically enable operation to continue for up to around 60 minutes although this can be extended through network management. In practice, even the capacity of well maintained batteries is notoriously variable.

System availability

24. Network operators can plan ahead and take seasonal variations into account and provide additional resources to prevent network failure during planned exceptional demand such as at New Year, major sporting events, etc. However, unplanned exceptional demand may exceed the available network resources or network failure may reduce the amount of resources available resulting in call blocking increasing to very high levels. An example of exceptional demand exceeding capacity was the congestion experienced in London following the bombings on the 7 July 2005.

25. As demand for communications services starts to approach network capacity access to the network, or parts of the network, must be restricted and traffic efficiently routed so that the network operates at or close to maximum capacity. If a network were not managed effectively, increasing traffic would eventually cause the equivalent of gridlock.

26. Mobile networks are sophisticated and dynamic in operation, base stations automatically transfer excess traffic to neighbouring base stations with overlapping coverage. Call traffic can be managed using a number of tools including call-gapping, half-rating, restricting roaming access and, use of ACCOLC (ACCess OverLoad Class) controls.

27. ACCOLC is a technique that GSM network operators use to manage access to their networks. It can also be used to give privileged access to front-line emergency responders in the event of congestion on networks in the immediate aftermath of an incident. Operators consider ACCOLC as the final option in the range of service management tools because, by using it, they are denying their customers service.

Privacy

28. GSM networks are not approved by CESG (see para 150) for voice or data that carries a government protective marking without additional appropriately accredited protection. However, GSM was designed to be more secure than earlier analogue systems by using a unique SIM (see para 162) to identify subscribers a unique identification for each terminal, authentication of connections and encryption of traffic. Encryption is typically only used between the terminal and base station; subsequent transmission, both wireless and across the PSTN (see para 137) remains largely unprotected against eavesdropping. The encryption used for authentication is vulnerable and it is only one-way: the terminal is authenticated to the network, there is no authentication of the network to the terminal. This means that it is possible to establish a false base station and fool the terminal that it is connected to the legitimate network in order to steal information contained in the SIM (see para 162) , disable encryption and eavesdrop on conversations. These exploits are difficult to perform since they require considerable technical capability. The casual user is safe from general busybodies 'snooping' on random conversations, however, they are not secure against determined attempts to intercept communications.

Other resilience issues with GSM

29. There are no network roaming agreements even for emergency calls. This means that a handset is tied to the service provider of the SIM whereas when a handset is used abroad it is common that the handset will either take service from a commercial partner of the home service provider or the network offering the strongest signal.

30. Many organisation's business continuity plans seek to mitigate shortfalls with GSM communications by using multiple SIMs from different network operators. However this approach is not without drawbacks. Handsets can be locked to a particular service provider preventing SIMs from other operators from working. While 'Pay as you Go' services may appear attractive, some providers reallocate telephone numbers if the handset has not been used for a period of time. Although this may not pose a problem for outgoing calls the handset may be inaccessible to incoming calls.

31. Other drawbacks are concerned with roaming on available UK networks using SIM issued by international operators. Manx Telecom is recognised as an international operator by UK networks and is convenient to use since destinations called in the UK do not require the UK country code prefix (00 44). However, network operators only allocate limited capacity for roaming users and permission for a handset to roam is sought by the handset from the operator issuing the SIM. This is can involve the use of international telephone circuits. On July 7th one technique that was used to manage the high volume of inward calls was to limit in-bound international trunk calls.

General packet radio services

32. General packet radio services, or GPRS, is a packet data service that is run over the GSM (see para 14) network. This enhancement was often considered as a *stepping-stone* to the next generation 3G (see para 45) service and is often referred to by the acronym 2.5G. GPRS services can be utilised in one-way (see para 159) or two-way communications. GPRS supports web browsing as a point-to-point (see para 161) service, while e-mail services can be used point-to-point or point-to-multipoint (see para 160). A typical consumer use of the service is to immediately 'push' incoming e-mails to the BlackBerry device.

Voice services

33. GPRS is principally a data service that is not particularly suited to voice. While GPRS can be used for voice, variable data rates and possible high time delays can result in data taking up to a second to transit the network, which can result in broken-up conversations.

Data services

34. GPRS connections differ from those used for GSM voice services (see para 16) in that once a terminal is 'attached' to a network (at which time an IP (see para 138) address is assigned) it becomes 'always on' until the terminal is either intentionally 'unattached' or the service is interrupted through a fault or congestion. As a consequence, the service suits the delivery of e-mail or web pages.

35. GPRS is an asymmetrical service in which the uplink and downlink connections are at different speeds: typically the downlink will be faster. The type of terminal and terms of

the contract under which the service is provided governs the bandwidth. Generally, service providers charge for the maximum bandwidth and amount of traffic rather than the connection time (which is more usual for GSM voice connections). The consequence of faster uplink speeds is that more power is used by the terminal, potentially resulting in shorter battery life.

36. GPRS uses a GSM timeslot to deliver a data rate of 14.4 kb/s. Higher speeds are possible if error correction is abandoned and, by using all eight GSM timeslots, a maximum bandwidth of 115 kb/s is possible. In practice, service providers make voice a priority and the maximum available speed is about 56 kb/s – about the maximum speed achievable from a dial-up modem but with the convenience of mobile connectivity. However, since the total bandwidth offered from a base station is shared with other GPRS users the available bandwidth will be less than the maximum.

37. Table 2 provides an indication of the time taken for (error-free) file transfers for files of various applications. An environment causing high error rates will increase transfer times as will any latency within the network. GPRS offers advanced, feature-rich data services such as colour Internet browsing, e-mail, powerful visual communications such as video streaming, multimedia messages and location-based services.

Table 2
Typical GPRS upload and download times for typical files

File Type	Approximate size (kilo byte)	Upload time @ 14.4 kb/s (second)	Download time @ 57.6 kb/s (second)
A page plain text for example 800 word email	5	2	Less than 1
A page plain text, 800 word "MS Word" document	25	13	3
Typical internet webpage	50	27	6
Mobile phone image, 176 x 220 pixels x 18 bit jpg	22	12	3
160 kb/s MP3 audio file, approximately a 4 minute track	3,800	2,160	540

Dependency on other systems

38. The GPRS network is dependent on the underlying GSM infrastructure (see para 21) and the additional infrastructure to support data service (shown in blue in Figure 2). The interdependency of the infrastructures is also reflected in dependency on grid-based electricity as described for GSM networks (see para 23).

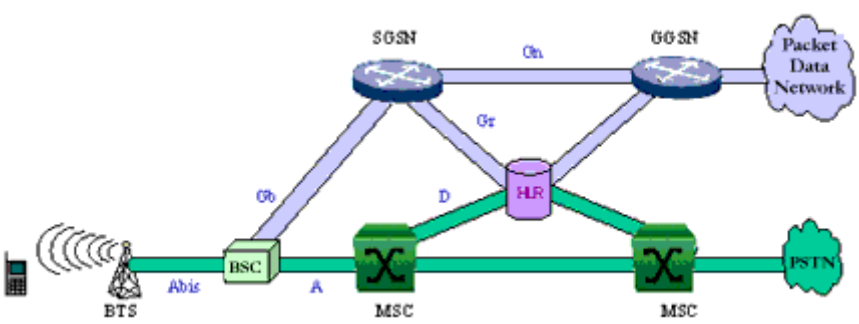

Figure 2. **Simplified architecture of GSM with GPRS**

39. The key elements of a GSM network handling data are: the **BT plcS**, or Base Transceiver Station, housing the radio transceivers that define a cell or sector and handles the radio-link protocols with the Mobile Station and assembles / dissembles data packets going to and from the terminals; the **BSC**, or Base Station Controller that manages the radio resources for one or more base stations, handling radio channel setup, frequency hopping, and handovers; the **HLR**, or Home Location Register which maintains the administrative information of each subscriber registered in the network, along with the last known location of the terminal; **SGSN**, or Serving GPRS Support Node which handles subscriber registration, authentication, location updating, and handovers in the packet domain (the location register function in the SGSN acts just as the VLR did within the **MSC**, or Mobile services Switching Centre, and stores subscription information and location information for packet switched services for each subscriber accessing the network via that particular SGSN); the **GGSN**, or Gateway GPRS Support Node, is the gateway between GPRS network and external packet data networks, converting between GPRS and Internet protocols and providing firewall and address translation services and manages roaming between GGSNs. The network architecture shown in Figure 2 may be simplified as the GGSN and SGSN may be co-located, reducing interconnectivity.

System availability

40. The GPRS data service is run over the same infrastructure used for the GSM voice service and hence the two are mutually dependent and are subjected to similar network management including the use of ACCOLC (see para 27). Although GPRS is an 'on demand' service and network resources are allocated dynamically, network operators generally place upper (and lower) limits on the available resources and for many, voice takes priority. Hence there are two forms of contention for available bandwidth within GPRS: that between GSM voice users and data users as to available network resources and that between the GPRS users.

41. Where there is a normal demand for voice, network resources for GPRS are allocated up to some network determined maximum. Individual GPRS users are allocated bandwidth from these resources up to the maximum determined by the class of their terminal. With rising demand, bandwidth to individual terminals is likely to be less than the maximum. This form of congestion reduces the speed of the connection during busy times and locations.

42. When there is a high demand for GSM voice, network resources dedicated to GPRS are reduced. Potentially as demand for voice reaches exceptionally high levels (such as that experienced in London on 7 July, 2005) the data service would be squeezed out altogether if minimum resources were not allocated. Under such circumstances, small sized files (such as e-mails without attachments or MSN style message data) are more likely to be transmitted. No congestion was reported by BlackBerry device users (see also para 44) even during the busiest period on 7 July, 2005, this was largely a consequence of the very small file size (around 2 kb).

Privacy

43. In general, the GPRS data service is not approved by CESG (see para 150) for data that carries a government protective marking without additional appropriately accredited

protection. As the service runs over GSM networks (see para 21) it suffers from the same vulnerabilities. In addition, connections needed to deliver data over the Internet or a company network incur additional vulnerabilities.

44. The BlackBerry Enterprise Solution™ by RIM (Research In Motion) provides a secure data service over GSM, for email (including viewing attachments) and mobile data services. This solution is approved by CESG (see para 150), subject to following their guidance, for storing and communicating government assets to RESTRICTED.

Universal Mobile Telecommunications System

45. Universal Mobile Telecommunications System, or UMTS, is also referred to as a 3G, or 3rd generation, mobile network. Although the underlying technology shares many of the characteristics of GSM it is very much more sophisticated and offers the promise of significantly higher bandwidth. UMTS is one of the International Telecommunications Union (ITU) family of third-generation mobile communications systems. UMTS uses a W-CDMA air interface, which lead some to refer to the technology as simply W-CDMA, which can lead to confusion.

46. To-date, 3G services have under delivered, in terms of connection speed, compared to the early hype and coverage is currently poor in comparison to that available from GSM networks and is concentrated in major conurbations and ground transportation routes. Operating at significantly higher frequencies (at around 2.1 GHz) than other mobile technologies (GSM is in the range 900 to 1,800 MHz) the resulting smaller cell sizes have led to very high infrastructure costs. Currently there is only one dedicated 3G network (operated by '3', a subsidiary of Hutchinson 3G UK Ltd) although services are also offered by O2, Orange and Vodafone. Where 3G services are not available the connection falls-back to the respective company's GSM service, '3' falls-back to O2. Geographic coverage can be assessed from following the link at reference 9. Future investment is likely to be directed to realising the promise of 3G, namely the availability of sufficiently high bandwidth to provide smooth delivery of video services.

47. UMTS offers teleservices (such as voice or SMS (see par 19)) and bearer services, which provide the capability for information transfer between access points. Using UMTS, it is possible to negotiate and re-negotiate the characteristics of a bearer service when a session or connection is established and during an ongoing session or connection. Both connection oriented and connectionless services are offered for point-to-point and point-to-multipoint communication.

Voice services

48. UMTS services in the UK were designed for compatibility with those services provided over existing core networks such as: ATM bearer services, IP-based (see para 138); GSM (see para 14) and ISDN (see para 137) services. The key telecommunications service in UMTS is voice but with the prospect of increasing bandwidth and multimedia support, UMTS will enable video calls and video conferencing.

49. Under normal conditions, perceived voice quality is slightly better than that of GSM, but less than that experienced over fixed-line telephony (see para 133). Under adverse conditions the improved voice quality is more noticeable for UMTS as it degrades

less quickly. Voice services within UMTS use Adaptive Multi Rate (AMR) coding. This means that the data rate used to convey the voice information and the amount of error correction for the data can vary dynamically to suit the conditions effecting the reception of the signal. This allows UMTS to increase the amount of error corrections when terminals are at the edge of coverage to prevent excessive degradation of voice quality. UMTS operators provide a similar range of user services to GSM providers (see para 16).

Data services

50. In the UK, UMTS providers utilise Wideband Code Division Multiple Access (W-CDMA) technology for the wireless connections between a terminal the base station (other incompatible technologies are used elsewhere). Both packet and circuit switched bearers are available.

51. UMTS is an asymmetrical service in which the downlink connection is faster than that of the uplink. Downlink connection speeds are determined by the cell size and the proximity of the terminal to a base station. Typical rates range from around 2.0 Mb/s for very small cells to 14.4 kb/s for continuous low speed data applications in very large cells. Currently, the maximum uplink speed is 64 kb/s. Actual values will depend on environmental conditions, distance from the base station, whether the terminal is on the move, and the number of other terminals accessing the same base station and their connection requirements.

52. One important feature of UMTS bearers is the possibility of guaranteeing a particular quality of service (or, QoS) for different applications or user groups. Quality of service attributes include: maximum and guaranteed speed; error levels; transfer delay and traffic handling priority. W-CDMA significantly improves the network time delays in comparison to GPRS. This makes it possible to tailor aspects of the bearer to the application. For example, applications such as voice or video are intolerant of any delay imposed by the network but may be tolerant of some data loss (resulting in degradation of the voice or picture quality), while other applications such as web browsing or retrieving data from a database would be tolerant of some delay but intolerant of error incurred in transmission. Not all 3G operators will activate the QoS attributes within their network.

Data rates

53. Table 3 provides a comparison of the time taken for file transfers for files of various applications in an environment without significant errors.

Table 3
Typical UMTS upload and download times for typical files

File Type	Approximate size (kilo byte)	Upload time @ 64 kb/s (second)	Download time @ 484 kb/s (second)
A page plain text for example 800 word email	5	Less than 1	Less than 1
A page plain text, 800 word “MS Word” document	25	3	Less than 1
Typical internet webpage	50	6	Less than 1
Mobile phone image, 176 x 220 pixels x 18 bit jpg	22	2	Less than 1
160 kb/s MP3 audio file, approximately a 4 minute track	3,800	480	90

Video message (20 sec) 176 x 144 QCIF, 10 frames/s	128,000	Less than 16	Less than 1

54. Video calls are not included in Table 3 as they require live continuous data compared to a video message that is delivered as a file. The slow uplink speed is just sufficient to deliver an acceptable experience for live video. However, this requires high compression which limits image size and any degradation in the uplink will result in jerky video quality.

55. Service providers are working to increase speeds and reduce time delays. Plans are well advanced to double the downlink rate with peak rates of between 1.8 and 3.6 Mb/s and increase the uplink rate to at least the current downlink peek rate of 384 kb/s. These enhancements use new technology which will not work with existing terminals.

Dependency on other systems

56. As with GSM networks (see para 21) and the data overlay GPRS (see para 38), all 3G networks are dependent on other telecommunications systems not only for calls leaving the parent network but also for calls originating and terminating within the same mobile network. The network operated by '3' is a dedicated 3G network. Other operators run 3G services over their GSM networks. Dependencies arise from the connections between the key elements of the network shown in Figure 3 which are frequently leased lines (see para 146) and generally are not under the direct control of the mobile network operator. Another dependency of the infrastructures is on grid-distributed electricity as described for GSM networks (see para 23).

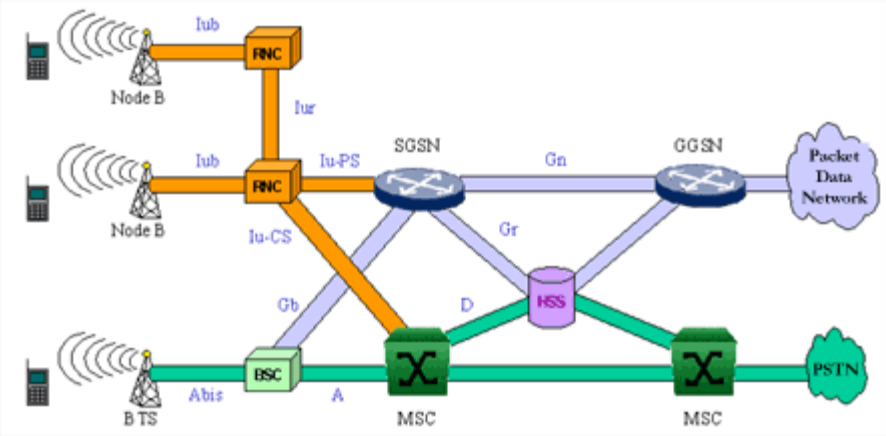

Figure 3. **Simplified architecture of UMTS**

57. The UMTS network can be viewed as a new radio access network (shown in orange in Figure 3) connected into the packet layer of the GSM/GPRS network. The new elements specific to UMTS are: the base stations identified as **Node B**, these are directly equivalent to those on the GSM network although they use a different access technology and frequency band, they house the radio transceivers that define a cell or sector and handle the wireless connections to terminals, where possible they are co-located in GSM base stations; the **RNC**, or Radio Network Controller, manages wireless resources for one or more nodes, they perform a similar function to that performed by a **BSC**, or Base Station Controller but they are more sophisticated and can perform many more functions without reference to the MSC or SGSN (see paragraph 39 for a description of the function of these elements).

System availability

58. Currently 3G networks are less likely to suffer congestion from unplanned events because take-up is below that which was projected when infrastructure was installed - a situation that is likely to change.

Privacy

59. UMTS improves on many of the limitations of GSM security (see para 28) with encryption based on stronger algorithms and managed in a more secure manner for both traffic and signalling. Encryption is used from terminal to Radio Network Controller (see Figure 3) and is network wide, not only on the 'air-side' between the terminal and the base station. The network authenticates both the base station to the SIM (see para 162) (contained in the handset) and *vice versa*. However, UMTS is not approved by CESG (see para 150) for voice or data that carries a government protective marking without additional appropriately accredited protection.

WiFi

60. Wi-fi is wireless networking - the ability to connect to a network or PC using radio (as opposed to network cabling). It's faster and has a greater range than Bluetooth, and is ideal for home or office connectivity. Using a wi-fi setup with your PDA or laptop means that you can share a broadband or dialup Internet connection, swap files, or share a printer or CD ROM between computer users. Wi-fi comes in two speeds: 802.11b (data transfer rates up to 11 megabits per second) or the newer to 54 mbps, 802.11g (data transfer rates up to 54 megabits per second). This compares with Bluetooth's much slower speed of 0.57 megabits per second. There's a newer standard, 802.11n due in 2007 that offers even faster connectivity. Devices based on the 802.11g standard are backwards compatible with 802.11b equipment, maybe a better investment. Wifi 802.11 operates in the 2.4GHz frequency band (as with Bluetooth and microwave ovens), and has a typical range of around 500 feet (with clear line of site). Indoors, you can expect around 150 feet with 802.11 - this will increase with the 802.11n protocol.

61. Reduced range, line of site, Campus only.

Wimax

62. WiMAX (802.16) which stands for Wi (WiFi) Microwave Access (MA) is an evolution of today's wifi technology using similar coding techniques including OFDM (Orthogonal Frequency Division Multiplexing). The step change is that WiMAX allows many channels to be run close to each other enabling greater data throughput. The other major difference is that WiMAX is likely to run on licensed spectrum rather than the free for all that is WiFi (802.11), the advantage here is that the greater number of channels reduces the need for re use and so the signals can be allowed totravel much further.WiMAX with it's many channels and use of licensed spectrum can be used to great effect in a metropolitan area where it is most likely to be used for last mile internet access, finding a way round the cable and telecoms providers and providing high speed low cost internet to consumers unlike WiFi (802.11) that is limited to hot-spots.There have been many rumours of streetlamp becoming WiFi masts and perhaps WiMAX is the technology to make this happen. These kinds of application are likely to be in the 10 - 66Ghz range allowing a reliable service to be built on licensed spectrum.

63. Currently mobile IT solutions based on Intel products.

64. In development, could be 10km or more.

Bluetooth

65. Bluetooth is a wireless technology that allows computers, phones and other devices to talk to each other over short distances (typically about 10 meters). Bluetooth uses radio waves (in the 2.4 Gigahertz range), and is designed to be a secure and inexpensive way of connecting and exchanging information between devices without wires. Bluetooth can be found in many of the newer mobile phones, handheld computers, laptops, printers, handheld organisers, as well as in all sorts of products. It uses a common protocol, so transmission of data (and voice) between two Bluetooth devices from different manufacturers should be straightforward. Uses of Bluetooth include: exchanging business

cards, sending data over a modem, sending voice from a headset to a mobile phone, and real-time satellite navigation using GPS.

66. Very short range, inter-device links only.

DECT

67. DECT is a digital wireless technology which originated in Europe, but is now being adopted increasingly worldwide, for cordless telephones, wireless offices and even wireless telephone lines to the home. The younger brother of GSM - Global System for Mobile - it is by contrast a radio access technology, rather than a comprehensive system architecture; DECT has been designed and specified to interwork with many other types of network, such as the PSTN (conventional telephone networks), ISDN (new digital and data phone networks), GSM (mobile phone networks) and more. As DECT becomes a true commodity technology, so in the future we may find cheap DECT modules incorporated in many of today's building control and security systems, providing intelligent systems that allow automatic control and alerting, augmenting and replacing today's customised telemetry and wired systems and proliferating into similar applications in the home, such as automatic security alerting in the event of unexpected entry, fire or flood, remote telephone control of appliances, return channels for interactive television, and many more. Wireless Local Loop (WLL) systems have been developed sucessfully using the DECT standard and may see future applications for eliminating the "last mile" copper circuits dominated by the major TELCO's.

Mesh networks

68. A mesh network is essentially a series of nodes – wireless access points typically mesh routers but also laptops, PDAs and the like – which route data to each other. There are two types of mesh networks, one where every node is connected to every other node and another, known as a partial mesh network, where each node is only connected to some of the others in the network. To get to a base station, users simply create a path by 'hopping' between nodes. Mesh networks are also handy for building temporary networks in places like festivals or conferences, or even for the military or emergency services on an ad hoc basis. Mesh networks could also find favour as a means of dodging costs associated with rolling out extra Ethernet in SMEs or universities. MESH networks are available using WiFi nodes controled by rugged lap-top PC's and could provide a viable system for rapid deployment in emergency situations.

69.

Wide area paging systems

Overview

70. Wide area paging systems are data only messaging systems with no voice capability. The systems are one-way (see para 159) as the message is 'pushed' to the pager terminal. The recipient cannot use the terminal for out-going communications. A number of terminals can be registered in a group so that all the pagers in the group can be alerted with the same message, this facility may be useful when calling out members of emergency teams. The depiction of the message presented at the terminal depends on the type of terminal and service provided. The most basic service provides a visual or aural alert typically associated with a prearranged action by the recipient. More sophisticated terminals can be used to display only numeric or alpha-numeric messages. There are two providers of wide area public paging networks: PageOne and Vodafone. Both offer similar services and claim coverage of 98% of the UK population including Northern Ireland.

71. Paging systems operate at relatively low speed, typically ranging from 1.2 to 6.4 kb/s on each outbound wireless channel. Effective data rates are even lower since the over-the-air protocols include an overhead needed for batching, error detection and correction. Both messaging systems use the Motorola FLEX™ protocol. Paging systems operate at a comparatively low frequency (most operate in the range 137 - 173 MHz) and as a consequence reception inside buildings tends to be better than devices that operate at higher frequencies although this will depend on atmospheric conditions and distance between the terminal and base station.

Dependency on other systems

72. Both paging systems are dependent on other infrastructures for both initiating and delivering messages.

73. Both service providers enable messages to be initiated in several ways each presenting different dependencies. Messages are typically initiated either indirectly through a voice call to a service bureau or directly from a touch-tone (see para 154) terminal (such as a telephone connected to the PSTN (see para 137) or mobile handset connected to a PLMN (see para 13)) or over the Internet using services such as e-mail or web browsing. Congestion in core communications networks (see para 132) or leased lines (see para 146) may affect the ability to initiate a message.

74. Both network operators depend on other telecommunications systems for both for the transmission of messages to their distribution networks and for transmission over their distribution networks to base stations. PageOne uses a geostationary satellite system

(see para 112) to transmit messages to their base stations while Vodafone uses a network of leased lines (see para 146). Potentially, both are vulnerable to failures of core communications networks (see para 132) which are used to control and monitor the operation of their base stations. Both service provider's base stations are completely independent of the PLMN (see para 13).

Dependency on grid-distributed electricity

75. Both paging networks are dependent on grid-distributed electricity and have fall-back electricity supplies at their network management centres. Base stations are not provided with back-up generation capacity, however exceptions exist where they are located at premises with arrangements for back-up electricity such as hospitals or key telecommunications facilities. At base stations, following a grid-distributed electricity failure battery back-up will typically enable operation to continue for between 4 to 12 hours. In practice, even the capacity of well maintained batteries is notoriously variable.

System availability

76. Pager networks are one-way (see para 159) connectionless broadcast networks unlike a conventional circuit switched telephone network a connection is not established between the sender and the recipient during the transmission of the message. When a message is entered into the system it need not necessarily be transmitted immediately. Messages are sent once only and not stored for re-broadcast. This has significant implications for message delivery. Unlike an SMS (see par 19) message sent over a PLMN (see para 13), if the recipient terminal is not available, for instance if it were switched off or outside radio coverage, the message will not be received. However, the above features render pager networks largely immune to crippling congestion at times of high demand. The principal consequences of very high demand are likely to be with the operator services resulting in an increase in the time taken for a message to be delivered.

Privacy

77. Wide area paging systems are not approved by CESG (see para 150) for any message that carries a government protective marking without additional appropriately accredited protection. If privacy is an issue rather then resorting to encryption technologies it is probably more expedient to ensure that information contained in a message is only intelligible to the intended recipient.

Mobile radio communications systems

Overview

78. Mobile radio communications systems embrace a wide range of technologies from essentially short-range basic walkie-talkies for voice conversations (operated without a licence over a few radio channels) to sophisticated systems such as Airwave, a nation-wide trunked (see para 165) system providing sophisticated voice and data services for the Emergency Services community. Further details on mobile radio communications technologies can be found at reference 15. Radio communications systems are the backbone telecommunications choice of many organisations including: the Emergency Services; those responsible for managing national and regional utility distribution networks (such as water, gas and electricity); taxi and minicab operators; operators of vehicle fleets (for example, road hauliers and road gritters); the AA and RAC and for local communications on construction sites.

79. Mobile radio communications systems work at many different frequencies in the electromagnetic spectrum, which, in the UK, is managed by Ofcom (see reference 5). Through licensing arrangements, Ofcom manage the range and the use of systems. Holding a conversation on a basic systems can be difficult, especially where there is a high density of users, a conversation will inevitably involve frequent channel switching as a stronger signal from other users will break into an established conversation. The more sophisticated trunked systems use a number of linked channels that enable a terminal using the network to choose the next available free channel, rather than wait for a particular channel to become free. This reduces call waiting time and also improves the efficiency with which the radio spectrum is used. Signalling is also used to identify and separate the individual customer groups sharing the service.

80. Here we group mobile radio communications systems into three categories:

(1) **Short-range unlicensed systems** (see para 84) which provide an entry-level, voice service.

(2) **Wider range, or private business radio systems** (see para 85) providing voice and data services.

(3) **Airwave** (see para 89) is only available to a closed user community consisting of the Emergency Services and Public Safety users.

Types of voice service

81. The service aspects of voice communication using mobile radio communication systems have some notable differences from those services offered by PLMN (see para 13) operators. At the most basic level, communications are simplex (sometimes referred to as half-duplex) (see para 163) in which communications at any one time are only one-way and broadcast to all terminals on the same receive channel, this type of service is often referred to as 'all-informed' in contrast to duplex (see para 166) communications. Simplex communications equipment is usually in the 'ready to receive' mode and initiating a voice message usually involves pushing a 'talk button'. Effective one-way communications, particularly within a group, relies all members of the group adhering to agreed protocols for conversations.

82. More sophisticated systems provide a wider range of call types. Trunked systems (see para 165) (such as those underpinned by the MPT 1327 and TETRA (see para 164) standards) enable virtual networks of terminals to be established providing a point-to-multipoint (see para 160) service. These virtual networks of terminals are often referred to a talk-groups. In a **group call**, only those terminals belonging to the same talk-group can hear and participate in the call. Typically the call is initiated by pressing the 'push-to-talk' button on the terminal which enables all terminals in the same talk-group to hear the communication. Typically, a group call will include a dispatcher working within a control room environment and members can readily be added or removed from the group. A **broadcast call** is a one-way (see para 159) group call where the calling party can be heard by the recipients but where there is not the facility for any of the called parties to reply. An **emergency call** is established by pressing a special call button to set up a high-priority call to a dispatcher or a predefined talk-group. **One-to-one**, a private point-to-point (see par 161) service can enable calls to the PSTN (see para 137) and PLMNs (see para 13). A **priority call** commandeers the network resources needed to establish the call and under conditions of high use, lower priority calls are likely to be 'dropped'.

83. TETRA -based (see para 164) services offer two additional call types: direct mode operation and ambience listening. In **direct mode operation**, two or more terminals communicate, walkie-talkie fashion, without involving a base station. This mode enables communication in areas where network coverage is not available and can be used to temporarily extend coverage in a limited manner. A dispatcher may place a radio terminal into **ambience listening** mode to covertly listen into whatever is picked up by the terminal's microphone.

Short-range unlicensed systems

84. A private mobile radio system called PMR 446 provides an entry-level analogue radio communications. PMR 446 provides short-range (2 km maximum outdoor), voice only service for communications between two or more terminals without the use of base stations. This system typically finds use for short-range communications on construction sites. Equipment operates in one of sixteen channels around 446 MHz and any handset within range of a transmitting handset can listen. Operation does not require a license which enables commercially available equipment to be operated straight out of the box. PMR 446 is a "free for all" public service – no one user or organisation has any greater right to use any channel over another, it is shared by all users which have an equal

priority. In order to hold an uninterrupted conversation users may have to switch channels, as a consequence users need to have agreed protocols for switching channels and this may not be a suitable technology for responders particularly in areas of high user density.

Wider range, and private business radio systems

85. Radio communications systems with a wider range are often referred to as Private Business Radio, or PBR, systems - a term that reflects the main community of users. This category includes systems that provide local or regional coverage through repeater or community base stations (see para 86). In urban areas handheld equipment can operate up to 7 km whereas more powerful vehicle mounted equipment, operating as part of a dispatcher service, can have a range up to 30 km, possibly doubling in rural areas. Services and equipment can be purchased or hired and further details, including geographic coverage, can be found through a trade association at reference 13.

86. A Community Repeater or Community Base Station (CBS) is a repeater station, usually situated on a hilltop or high mast, which gives a range of around 60 km in all directions. A repeater station is a normal Base Station which uses talk-through to retransmit all that it receives. CBS services can provide cost effective coverage between fixed and mobile units where increased range is needed but where the fleet size makes it too expensive to install and run a private system - courier firms would represent a typical class of users. A CBS usually operates on a single channel and users share this channel on a time basis - when one user is speaking all other users are locked out and cannot overhear the conversation. Charges are normally a fixed monthly fee per vehicle. As there are no call charges, this system favours the users who have a high volume of calls and wish to service a fixed area.

87. The only commercial service with wide geographical coverage is operated by Fleetcomm (see reference 4). Their push-to-talk services are concentrated in major metropolitan areas with that bounded by the M25 enjoying a fast call set-up service. In addition to voice services two data services are supported: short predefined messages and standard two-way, point-to-point (see para 161) data at a speed of 150 bytes/s (with higher speeds available). This is an analogue service run over digital trunking (see para 165).

88. RAYNET, the Radio Amateurs' Emergency Network, (reference 14) is a voluntary organisation of Radio Amateurs who can provide an alternative communications system at times where existing systems are degraded or unavailable. They are able to offer local, national and international services for civil emergencies, exercises and local community events. The network is capable of handling speech, image and data communications at speeds up to 9.6 kb/s. Although the network may use the fixed infrastructures such as PSTN, Internet and mains power, to deliver services or for mobilisation, resilience is central to their operations. Under the terms of their radio licence RAYNET can pass on messages for the Category 1 and 2 responder community and voluntary organisations. The local provision of services is demand-led and contact should be established with local groups. Further details can be found via reference 14.

Airwave

89. Airwave is only available to a closed user community consisting of the Emergency Services and Public Safety users. The parts of the radio spectrum that are used by Airwave

have been set-aside for meeting mobile communications requirements of all UK Emergency and Public Safety services. Currently, application for Airwave services is made to Ofcom (details can be found at reference 6). As apart of a wider review of resilient telecommunications, CCS (see para 149) in Cabinet Office is currently reviewing entitlement to Airwave and other privileged telecommunications services (see ACCOLC (see para 27)) and GTPS (see para 143)). Airwave is only provided by Airwave Ltd, a wholly owned subsidiary of O2 plc. Airwave is a secure public digital mobile radio service based on technology which comes from the same stable as public GSM (see para 14) mobile telephony.

90. Airwave is the only national radio communications voice and data services with geographical coverage from all metalled roads in the British Isles. Canadian-based Dolphin Telecom was a competitor, also using TETRA (see para 164) technology. However, the popularity of GSM networks (see para 14) left little room the service offered by Dolphin and it was forced into receivership in June 2002. Dolphin was subsequently bought by Inquam UK which subsequently went into receivership. The spectrum released is to be auctioned by Ofcom (see reference 5), scheduled for autumn 2006.

Voice and data services

91. In addition to the voice services outlined above (see para 82) Airwave also provides data services. A **short data service** enables messages up to 256 characters to be used for basic status messaging, location information, and free form text message applications in either point-to-point (see par 161) or point-to-multipoint (see para 160) call configurations. **Circuit-switched data services** provide data speeds up to 28.8 kb/s, although the actual value is dependent on the resources used increasing the level of error correction decreases the speed. A number of different **Packet Data Services** are also supported that enable access to IP (see para 138) supported services.

Dependency on other systems

92. Airwave is currently dependent on BT plc core networks (see para 132). This dependency for connections between the nodes is being reduced. A project called Ground Based Network Recovery will remove this dependence through separately and diversely connecting the network of dominant base stations. The programme will consist of replacing the existing transmission links with a network of microwave links that will automatically reroute on failure. Phased implementation will commence during 2006 and be complete by August 2007.

Dependency on grid-distributed electricity

93. At present, following local grid-distributed power failure base stations can continue operation on battery supply for six hours, which can be extended through network management. When the Ground Based Network Recovery project (see para 92) is complete each site that is part of this network (approximately one third of all Airwave sites) will be able to continue operation for 7 days. Power supply is envisaged to be provided by either a built-in generator or by one that can be provided under contract at short-notice. A small number of sites (between 70 and 80, approximately 2.5% of the total) that include the key switches are co-located in BT plc premises. These sites are provided with batteries and on-site automatically activated standby generators capable of operating continuously for 14 days without on-site attendance.

Privacy

94. Airwave is accredited by CSIA (see para 151) to carry voice and data to a protective marking of RESTRICTED.

Other resilience issues with radio communications systems

Familiarity with terminals

95. Although handsets used in radio systems may resemble ruggedized GSM terminals voice services (see para 82) require additional features such as, a means of selecting talk-groups (often via a thumbwheel located at the rear of the terminal) or the means used to initiate an emergency call, or even the 'push-to-talk' button that is fundamental to the operation of most voice services. In addition, the location of the microphone is likely to be counter-intuitive for users familiar with handsets connected to PLMNs (see para 13). While use of these features become familiar with frequent operational use they can prevent effective use by untrained users or those that only use such equipment for contingency use.

Operation of talk-groups

96. Talk-groups are a feature of trunked systems (see para 165), although all terminals receiving on the same channel of a more basic system could be considered to be a 'talk-group'. Although talk-groups enable more efficient use of spectrum, more importantly, they group together terminals that operationally need to be part of the same conversation. In a group call, only those terminals belonging to the same talk-group can hear and participate in the call - those terminals that are not part of the same talk-group are not included in the conversation. Management of talk-groups is therefore central to providing an effective response using trunked radio systems - those needing to share tactical information need to be part of the same talk-group.

Use of protocols

97. Effective two-way voice communication over a simplex (see para 163) system requires adherence to agreed protocols, sometimes referred to as 'radio discipline'. Such protocols are less important where communication is duplex (see para 166) although conference calls inevitably benefit from using agreed protocols, such as when a new party enters or leaves the conference. Agreed protocols become particularly important where the parties to a conversation do not enter into regular dialogue over a simplex system, such as when responders from different organisations need to co-ordinate efforts to respond to an emergency. Failure to adhere to agreed protocols is likely to significantly reduce the effectiveness of conversations since parties will effectively cut one another off when they depress the 'talk button'.

Satellite telecommunication systems

Overview

98. Assessment of the resilience of satellite telecommunication systems are far from straight-forward. Apart from the issues that arise from two broad families of satellite, significant differences exist in the way in which a connection is established, whether communications are restricted to between terminals connected to the same satellite provider, whether traffic switching involves ground-based infrastructures or whether it is carried out in orbit between satellites in the same constellation and whether part of the communication link is established over another network: possibly a PLMN (see para 13), a PSTN (see para 137) or is Internet-based.

99. Commercial satellite communication systems that provide UK geographical coverage all provide two-way (see para 166) point-to-point (see par 161) voice and data services. Here we group satellite-based communications networks according to the nature of the orbit of the satellite, which determines attributes of the services available:

(1) **Satellites in geostationary orbit** (see para 112) and

(2) **Satellites in low earth orbits** (see para 100)

Satellites in low earth orbits

100. Satellites that are relatively close to the earth (at between 500 and 1,500 km) are referred to as being in low earth orbits. These satellites encircle the earth passing periodically overhead. Globalstar (see para 103) and Iridium (see para 108) provide systems with coverage of the UK. Further details of geographic coverage can be found at reference 8.

101. The relative closeness of these satellites to earth has many advantages. The signal strength is considerably higher than satellites in geostationary orbit (see para 112) which enables the use of handheld terminals that are about the same size as large PLMN (see para 13) handsets and weigh less than about 500 g. The comparatively short distances that the signal has to travel result in low round trip time delay (of approximately 0.03 seconds) which is hardly noticeable in voice conversations and compares very favourably to typical time delays of approximately a quarter of a second for geostationary systems, over which 'jerky' conversations are the result.

102. Because satellites in low earth orbits are moving relative to the earth a connection between a terminal and a satellite will be broken when the satellite moves out of line of sight unless the connection is 'handed over' to another satellite visible to the terminal. For example, for the Globalstar (see para 103) system, depending upon location and date, there is nearly always at least one satellite and potentially up to four in view. The likelihood of the handset being able to *see* a satellite increases proportionately to the amount of sky in view. The less sky that can be seen, the lower the likelihood that the communication will be seamlessly handed over with the result that established connection will be terminated. In practice, connections lasting more than a few minutes will require hand-over.

Globalstar

103. Handset terminals are similar to PLMN (see para 13) handset terminals in dimensions and weight. Terminals can work in two modes: connections are established only to the Globalstar satellite network or to both Globalstar and GSM 900 networks (such as those in the UK and Europe). In the dual service mode, the terminal can be configured to firstly attempt a connection to GSM 900 networks and if no GSM network is available then attempt to connect to the Globalstar network.

Voice service

104. Globalstar offers GSM quality voice services using handheld, vehicle or building mounted equipment. Customer services including voice mail and Caller ID are available. Contract and Prepaid billing are available.

Data service

105. Globalstar provides an SMS (see para 19) for up to 160 character messages that can be sent to and received from other Globalstar and GSM terminals. Globalstar also provides a bearer for data communications up to a speed 9.6 kb/s. This can be used to provide connectivity between PCs and PDAs using an appropriate physical interface for Group 3 fax, file transfer, Internet and e-mail services.

Call set-up and dependency on other systems

106. Globalstar terminals can make and receive calls from the PSTN (see para 137). The downlink of all UK registered terminals is to a ground station in France. This means that calls to and from the UK PSTN or PLMN (see para 13) will transit international gateways and the French telecommunications networks. Although Globalstar terminals usually have a French SIM (see para 162) and subscriber number, it is possible to assign a UK number using a number translation service. This enables calls originating in the UK from other networks to avoid placing an international call. Use of international networks has resilience implications. For example, when UK core networks (see para 132) are heavily congested (such as on the 7 July, 2005) the volume of inbound international calls is likely to be restricted.

107. When placing a call the terminal and the nearest earth station gateway must be within coverage of the same satellite. This is necessary because the gateway at the ground station and not the satellite performs call setup and switching. Even for calls placed between two Globalstar terminals the communication path is a 'two-hop' via the earth station. If the called party is on in interoperable infrastructure (such as the PSTN (see para 137) or PLMN (see para 13)), the call will be routed through French infrastructure to the recipient's country and national networks.

Iridium

108. Handset terminals are similar to GSM handsets in dimensions and weight. Terminals connected to the Iridium network are not compatible with UK GSM networks. Iridium currently provides services to the US Department of Defense.

Voice service

109. Iridium offer a voice service using handheld, vehicle or building mounted equipment. Customer services including voice mail, call forwarding, and call barring are available. Contract and Prepaid billing are available.

Data service

110. Iridium provides an SMS (see para 19) for messages up to 160 character that can be sent to and received from other Iridium and to GSM terminals via earth station gateways. Iridium also provides a bearer for data communications up to a speed 2.4 kb/s. This is a direct dial-up service that can be used to provide connectivity between PCs and PDAs using an appropriate physical interface for Group 3 fax, file transfer, Internet and e-mail services. Iridium also offer an alternative service called Direct Internet Data. With this service Iridium acts as an ISP offering bandwidth of up to 9.6 kb/s is available using compression applied at the Iridium earth station gateway.

Call set-up and dependency on other systems

111. The Iridium satellite system is based on a constellation of 66 satellites that switch calls between satellites making the system 'one hop'. This means that terminal-to-terminal calls using Iridium terminals need not use ground-based infrastructures. All calls to or from the PSTN (see para 137) are uplifted to the constellation using an earth station gateway. There are 16 gateways, those nearest to UK are in Düsseldorf and Rome.

Satellites in geostationary orbit

112. Satellites that are in geostationary orbit are in a very special orbit (approximately 37,500 km) directly overhead the equator. Satellites in this orbit are geosynchronous – they rotate with the earth and have the advantage that providing the orbit is maintained they always remain overhead. There are many satellite operators with UK coverage, however only Inmarsat (see para 113) and Thuraya (see para 118) offer a mobile communications service. Further details of geographic coverage can be found at reference 8.

Inmarsat

113. Inmarsat operates a constellation of nine geostationary satellites. Portable terminals that operate with these satellites generally have large antennas (resulting from the long communication paths) and while they can be considered portable (the smallest are the size of an attaché case) they cannot be used for truly mobile communications since during communication the antenna must point directly at the satellite. In the UK, geostationary satellites are located in the sky approximately 20 degrees above the horizon and antennae will require the same sighting as 'dishes' used to receive BSkyB television broadcasts. Inmarsat terminals are not interoperable with the PLMN (see para 13) in the UK.

Voice service

114. Inmarsat offer a telephony service with almost complete global coverage using portable, vehicle or building mounted equipment. Voice mail, call forwarding, call barring, caller / recipient identification are available but depend on the contracted services with the network provider and on the handset used. Contract and prepaid billing are available.

Data service

115. Inmarsat offers a range of data services from 2.4 kb/s (suitable for e-mails, messaging and Group 3 facsimile) to 64 kb/s with connections to the international ISDN (see para 137) networks to their BGAN, or Broadband Global Area Network, packet data service, which based on Internet protocol offers contended data rates up to 492 kb/s (although typical values are about half this figure).

Call set-up and dependency on other systems

116. Inmarsat terminals can make and receive calls from each other and to and from the PSTN (see para 137). Terminal-to-terminal calls are 'two-hop' involving an earth station. Calls to and from the PSTN are 'single-hop' via an earth station gateway.

117. Earth stations and the services through them are operated by independent organisations working in partnership with Inmarsat. Services contracted from a service provider are exclusive to that provider. Communications between Inmarsat customers of the same service provider are routed through that provider's earth station (and are 'two-hop'). Communications between Inmarsat customers registered with different service providers involves the communication being passed between the two earth stations, possibly over other networks.

Thuraya

118. Handset terminals are similar to GSM handsets in dimensions and weight. Thuraya terminals are GSM (tri-band) compatible. Terminals can be configured for three modes of

operation: satellite only, GSM only, or auto switching between the two all are subject to the airtime contract and installation of a compatible SIM (see para 162). Thuraya terminals contain a Global Positioning System (GPS). When a terminal is switched on there can be a significant delay, of more than 10 minutes, while the location of the terminal is established before a connection is established with the network.

Voice service

119. Customer services provided (subject to contract and type of terminal) include: voice mail, conference calls, call forwarding, call barring, call waiting and call hold. Contract and prepaid services are available.

Data service

120. Thuraya provides an SMS (see para 19) for messages up to 160 characters that can be sent to and received from other Thuraya and GSM terminals via the earth station gateway. Thuraya also provides a bearer for data communications up to a speed of 9.6 kb/s. This can be used to provide connectivity between PCs and PDAs using an appropriate physical interface for Group 3 facsimile, file transfer, Internet and e-mail services. A broadband data service provides speeds up to 144 kb/s over a GPRS (see para 32), service to portable laptop-sized equipment.

Call set-up and dependency on other systems

121. Thuraya satellites route terminal-to-terminal calls between Thuraya terminals independently of the earth station making these calls 'one-hop'. Calls out of the Thuraya network are routed through the earth station gateway located in the United Arab Emirates.

System availability

122. Recent emergencies such as Hurricane Katrina (Gulf coast USA, August 2005) and the bombings in London (July, 2005) have highlighted the role that satellite-based services can play in enhancing the resilience of telecommunications. As a consequence, the take-up of satellite services for contingency telecommunications has dramatically increased. Operators of satellite systems are particularly reluctant to discuss network capacity. Largely as a consequence of the cost of delivering satellite-based services operators seek to closely match day-to-day operational capacity and demand. Available capacity for contingency users in emergencies may be further reduced by commercial organisations, such as news agencies, establishing a connection and then keeping it open because of the uncertainty in regaining access. Many operators do not offer contracts for 'on-demand' use of reserved bandwidth. Where they do, the costs involved tend to be very high.

Other resilience issues with satellite systems

123. Because of the different modes of operation of satellite systems and high operational cost, routine operational use is less likely than with other technical solutions. Equipment procured solely for contingency use presents significant implications for resilient telecommunications.

Familiarity with equipment and systems

124. Although satellite handsets resemble familiar mobile handsets (used with PLMN (see para 13)) some features are invariably different. One terminal is particularly counter-intuitive - the operator keys in the connection information then turns the handset over, speaking into the rear of the handset with the keys facing away from the operator.

125. Antennas usually have to be deployed and then stowed after use, an operation that is unfamiliar to those using mobile handsets. Some handsets cannot be carried with the antenna deployed, the antenna has to be deployed in order to receive a call including notification of voice mail.

126. The use of international 'dial' codes even for domestic calls can lead to confusion.

127. Telephone numbers are likely to be unfamiliar and directories can become out of date.

Battery life and charging

128. Extended operational use requires a fully charged battery - operational time on battery is unlikely to match expectations gained from using modern PLMN (see para 13) handsets. Extended use will require additional fully charged batteries and access to charging facilities. Operational time on battery is highly dependent on a number of factors including: the age of the battery, the charging regime and the number of charge – discharge cycles. Ensuring deep-discharge is particularly important for nickel cadmium cells, though less so for the newer battery technologies, since shallow discharge will, over the expected life-time of the battery, lead to significantly reduced capacity. In practice, even the capacity of well maintained batteries is notoriously variable.

Terminals must be in line of sight of a satellite

129. All satellite-based systems require the antennae to have unobstructed visibility of the sky. Mobile terminals do not work reliably inside buildings even near a glazed external window. This limitation can be overcome by the use of externally mounted antennae.

Signal attenuation during severe weather

130. Mobile satellite systems operate at radio frequencies where water attenuates the signal. Signal attenuation can result in severely degraded communications and broken connections. Attenuation is a consequence of the length of the path that the signal has to travel, a significant proportion of which may be through rain or snow laden clouds in the lower atmosphere.

Interference from electromagnetic sources

131. The signal strengths from mobile satellite systems is much less than from handheld terminals connected to a terrestrial (PLMN (see para 13)) system. In urban areas and industrial locations, where a potentially harsh electromagnetic environment will degrade the performance of satellite communications.

Fixed telecommunications networks

Overview

132. Although 'fixed' telecommunications networks are often associated with the physical network, namely connectivity (the cable or optical fibre connections) and facilities (such as 'telephone exchanges') but this is merely a part of the means by which services are delivered. Services such as voice telephony, ISDN (see para 137) or higher bandwidth services such as KiloStream or MegaStream (provided by BT plc) are delivered using various protocols. For example, IP or Internet Protocol is the base protocol used to deliver services such as web browsing or e-mail over the Internet.

133. The physical network can be considered to consist of **core networks** (sometimes referred to as 'backbone'), these are high bandwidth transmission systems that connect together different locations (also variously referred to as 'nodes' or 'points of presence') where a customer gains access to the network and **access networks** (often referred to as the 'local loop' or 'last mile') that enable individual customer premises to connect into the core network. Both private circuits (see par 146) and virtual private networks (see para 147) can be run over core networks. Telecommunications networks are sometimes referred to as 'fixed' infrastructure because much of the physical infrastructure consists of copper (regular wires and co-axial cable) and optical fibre cables although other high bandwidth technologies such as microwave links and satellites are commonly used.

Dependency on other systems

134. Prior to liberalisation of the communications markets in the UK during the 1980's the communications infrastructures were owned and operated by the GPO. Today, the situation more closely resembles a market and although a number of core networks exist offering differentiated services, much is still owned by BT plc. The situation is very different for access networks which are still extensively owned by BT plc. Liberalisation of this market, through a process called 'local loop unbundling' is now beginning to have a significant impact. BT plc infrastructure has by far the widest geographic reach providing connections to nearly all residences and enterprises in the UK.

135. Generally, it is impractical for competing operators to completely replicate the scale of the BT plc network, so in addition to installing their own connectivity they may acquire capacity or facilities from BT plc or other operators in order to assemble their network. Connectivity is increasingly becoming a global commodity and the realisation of a

'communication link' or connection to a network is often far from clear. For example, domestic cable TV suppliers also offer telephony and Internet services over their own cable. While the cable to the customer's premises is independent of BT plc's network that seperacy may finish at the cabinet in the street where the service is often connected into the BT plc network. Communications may not be routed by the obvious least-distance path, routing is dynamic and is likely to be routed on a least-cost or least-congested basis and they are unlikely to remain completely within one service provider's infrastructure.

136. These issues can have important implications for the resilience of corporate telecommunications services. For example, it can be very difficult to gain assurance that two communications links, obtained for the purpose of providing resilience, are indeed truly diverse. The NISCC (see para 158) has produced a Good Practice Guide for Telecommunications Resilience (reference 1), providing a helpful starting point from which to assess resilience. As a consequence, the same material is not covered here.

The public switched telephone network

137. Public telephony services in the UK have been evolving since the latter part of the 19 Century and the early analogue systems (with manually connected, or switched, services) have essentially been replaced by digital services. ISDN, Integrated Services Digital Network, was an early type of circuit switched telephone network system, designed to allow digital transmission of voice and data over ordinary telephone copper wires, which resulted in better quality and higher speeds than available with analogue systems. Evolution of telephony is also reflected in the terminology associated with voice services. The public switched telephone network, or, PSTN, is a term frequently used interchangeably with, 'fixed telephony' (to distinguish it from mobile networks), 'circuit switched voice' and 'POTS', or Plain Old Telephony Service (although the PSTN refers to the network and POTS to the service run over the network).

138. The development of the Internet has had a profound effect on telecommunications. Early infrastructures were developed for specific services but now digital technologies and the Internet now enable services to be run over one infrastructure. Initially accessible through dial-up connections using a modem connected into the PSTN, access is now routinely accessible over a high speed 'broadband' connection. Services provided over the Internet, such as e-mail and web browsing are based on IP (or, Internet Protocol).

139. The core communications networks in the UK are about to be completely overhauled and all the existing services (see para 132) converged on a single technology based upon the Internet Protocol. These networks are referred to as 'next generation networks' or NGN. BT plc is commencing the roll-out of it's NGN in South Wales during the autumn (2006). Further details of communications networks and associated resilience issues can be found at reference 7.

Availability of the PSTN infrastructure

140. The majority of traffic on the PSTN traverses BT plc networks (the figure is around 80%, but depends on geographic location and traffic routing). This network has been designed and is managed to provide a very high level of availability (typically referred to as five nine availability or 99.999% available). Customers premises are connected to the core network through an access network consisting of 'concentrators' and 'switches' which are in turn connected to a hierarchical network of 'switches' that route calls throughout the

core network. Although the term 'exchange' is still frequently used it has largely been replaced by the term 'switch'. The connections between the switches are arranged to ensure that the network is resilient to failure of both the switches and the connections between them. In practice, resilience decreases towards the periphery of the network and a customer is most exposed when singly connected.

Dependency of services on grid-distributed electricity

141. The PSTN is highly resilient to failure of grid-distributed electricity. Access and core infrastructure has battery back-up that cuts-in immediately on failure of the local grid-distributed supply. This arrangement is augmented by local generators that can typically run for 14 days consecutively.

142. Terminal equipment, such as telephones and private branch exchanges, or PABXs, may or may not continue to function on failure of the local electricity supply depending upon the nature of the equipment. For example, PABXs are typically installed by a customer to provide connection into the access network, if the equipment is not provided with back-up power, services on the 'customer side' will fail on failure of the local electricity supply. Individual telephones connected into the access network are typically powered by the network. However, certain types of wireless telephone such as DECT (see para 153) terminals are not powered by the network will cease to function on local power failure. The situation with services provided by cable companies (NTL or former Telewest) should be clarified with the service provider.

Government telephone preference service

143. Access to the PSTN can be enhanced for privileged users by a service called GTPS, the Government Telephone Preference Service. The preference scheme was developed during the Cold War as a fall-back measure to be activated in the event that either electricity became scarce or access to the telephone network needed to be restricted. When invoked, equipment that is not part of the preference scheme is completely disconnected – there is no 'dial tone' for anyone not on the privileged access register. The draconian consequences of invocation has resulted in this facility being used very rarely.

144. Next generation networks will enable a more useful call preference service to be offered. Referred to as 'enhanced' GTPS (or EGTPS) this service will enable calls initiated from registered equipment to have a very high likelihood of completing, by way of priority over other calls as the registered call crosses the network. In view of the imminent roll-out of the NGN and the limited utility afforded by GTPS we are not encouraging the uptake of the legacy service.

Private circuits and virtual private networks

145. A private circuit (see para 146), also referred to as a 'leased line', provides a physical communication path between specific locations over dedicated infrastructure. In comparison, a virtual private network (see para 147) uses 'virtual' connections to route communications over a shared network, that could be the Internet or a service provider's network. The connections are referred to as being 'virtual' because they are only formed 'logically' regardless of the physical structure of the underlying network. These logical connections are dynamic, allowing the bandwidth and other resources to be shared.

Private circuits or leased lines

146. Private circuits or leased lines provide permanent or semi-permanent dedicated connections between two specified end points. The 'lines' consist of customer access bearers connecting each facility into the provider's network through a permanently open channel within the provider's network. Private circuits can be used to connect individual facilities together or to create the backbone for a private wide area network onto which many facilities can be connected. Private circuits are suitable for voice and data connectivity and have traditionally been a popular solution for connecting facilities at geographically dispersed locations, for example, linking a facility to the Internet, or providing remote network access. They are most cost effective where traffic is heavy and steady such as between local area networks. Management of the network becomes an increasing overhead as complexity increases. Private circuits are usually contracted for a fixed period and the charging structure is based on dedicated bandwidth of the circuit and the transit distance. Capacity can typically vary from simple analogue circuits for voice and low speed data to digital lines with standard multiplex capacities through to multi-gigabit bandwidths using optical fibre based connectivity.

Virtual private networks

147. Virtual private networks (or VPNs) are increasingly becoming the preferred means of providing connectivity for facilities and remote workers. VPNs provide a flexible means for delivering data and voice services, increasingly as VOIP (voice over Internet protocol). Further information on VOIP is provided by the NISCC (see para 158) (reference 3). Access to the service provider's point of presence on their network achieved through a gateway using a number of options including: leased line (see para 146); Internet connection or 'dial-up' circuit. As communications are established over a shared network privacy is usually achieved using encryption and this overhead effectively reduces the capacity of the connection. Gateways to the VPN manage security using protocols to enable the establishment of virtual point-to-point connections or 'tunnels', through the shared network. Further information on virtual private networks is available from the NISCC (see para 158) (reference 2).

Terminology

148. **ATM**, Asynchronous Transfer Mode is a connection-oriented network technology. The connections are not physical end-to-end connections like a circuit switched telephone network. ATM connections have properties that describe the type of traffic carried over the connection and the way it is treated by the network. The properties, such as Traffic Descriptors or Quality of Service parameter are negotiated at the time of connection.

149. **CCS**, the Civil Contingencies Secretariat based in Cabinet Office, visit us at www.ukresilience.gov.uk contact us at resilient.comms@cabinet-office.x.gsi.gov.uk.

150. **CESG,** Communications Electronics Security Group, the National Technical Authority for Information Assurance. Visit them at www.cesg.gov.uk.

151. **CSIA**, the Central Sponsor for Information Assurance, based in Cabinet Office. The CSIA provides a central focus for information assurance in promoting the understanding that it is essential for government and business alike to maintain reliable, secure and resilient national information systems. Visit them at www.csia.gov.uk.

152. **Coverage**. Service providers use different bases, the basis is always worth closer inspection. For example, x% coverage of the UK land area would reach more of the UK population than the same x% coverage of the UK population. There may also be substantial local variation in the availability of the service, for example private mobile radio systems often have patchy availability when the receiving terminal is not in line of light of the transmitting antenna. The measure used here is geographical coverage.

153. **DECT**, Digital Enhanced (formally European) Cordless Telecommunications is an ETSI (see para 155) standard for digital portable telephones, commonly used both domestically and corporately.

154. **DTMF**, dual-tone multiple frequency signalling is used for call setup between a terminal and a telephone exchange also known as 'Touch-Tone'.

155. **ETSI**, the European Telecommunications Standards Institute, responsible for standards such as DECT (see para 153), GSM (see para 14), and TETRA (see para 164).

156. **kb/s** communication speed, or bandwidth, expressed in kilo (thousands) bits per second.

157. **Mb/s** communication speed, or bandwidth, expressed in mega (millions) bits per second.

158. **NISCC**, the National Infrastructure Security Co-ordination Centre. The role of NISCC is to minimise the risk to the critical national infrastructure (CNI) from electronic attack; other parts of government work to protect the CNI from physical attack or natural disasters. Visit them at www.niscc.gov.uk.

159. **One-way communication**. The direction of communication is one-way or unidirectional. At the most basic level information can be *pushed* to the terminal such as when a pager message is delivered.

160. **Point-to-multipoint communication**. Communications can be established from one terminal to many other terminals, examples include a telephone conference call which is also two-way and a broadcast call over a private mobile radio system from a dispatcher

to all terminals tuned in to receive on a particular channel or talk-group, this type of service is often referred to as 'all-informed'.

161. **Point-to-point communication.** Communications can be established from one terminal to another specific terminal. For example, telephone 'subscriber' numbers are used to establish duplex, point-to-point communications where the called party and the caller are the only parties in the conversation.

162. **SIM**, Subscriber Identity Module is used in mobile handsets connected to Public Land Mobile Networks to store information about the network and user selected information, it resembles the 'chip' on a credit card.

163. **Simplex** (sometimes referred to as half-duplex) is two-way communication is, at any one time, only one-way.

164. **TETRA**, a hybrid digital trunked radio standard that closely resembles GSM for public land mobile (cellular) telephony. TETRA was developed by the ETSI (see para 155). In trunked systems, a number of radio channels are pooled together and allocated dynamically to users. TETRA is an open, global voice and data standard used in Europe and elsewhere (for example: Northern Ireland: Police Service, Channel Islands: Emergency Services, Utilities and Taxis; UK – Birmingham International Airport; Norway; the Netherlands: Police; Singapore and China).

165. **Trunking** is a technique used to increase the efficient use of bandwidth. For example, a trunked radio system is a radio system used to maximize available capacity in a two-way radio system by giving groups of terminals a logical 'talk-group' to share for their communications, rather than a dedicated radio frequency. Terminals send data packets, on a dedicated frequency, called a control channel, to request communication on a specific talk-group. A digital signal is then sent to all terminals monitoring that talk-group, instructing the terminals to automatically switch to the frequency indicated by the system to monitor the transmission. After the conversation is finished, the terminals return to monitoring the control channel for additional transmissions. This arrangement allows multiple groups of users to share a small set of actual radio frequencies without hearing each others' conversations.

166. **Duplex communication.** The direction of communication can occur simultaneously in both directions, such as with normal voice telephony over fixed networks, also referred to as bi-directional communications.

Further information

1. **Telecommunications Resilience, Policy and Best Practice**. Id 00393. NISCC. May 2004. Available at http://www.niscc.gov.uk.
2. **Virtual Private Networks (VPNs)**. Viewpoint 03/2006. NISCC, 2006. Available at http://www.niscc.gov.uk.
3. **Voice over IP**. Viewpoint 01/2006. NISCC, 2006. Available at http://www.niscc.gov.uk.
4. **Fleetcomm** visit them at www.relcom.co.uk
5. **Ofcom** is the independent regulator and competition authority for the UK communications industries, with responsibilities across television, radio,

telecommunications and wireless communications services**.** Visit them at http://www.ofcom.org.uk/

6. Application details for Airwave can be found at: http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/business_radio/emergency/app_guidelines/#content

7. **Telecommunications Networks – a vital part of the Critical National Infrastructure.** Document prepared by Peter Walker for CSIA, Cabinet Office, 2005. To be available at http://www.ukresilience.info.

8. Details of satellite geographic coverage can be found at http://www.satphone.co.uk/

9. GSM geographic coverage can be found at http://www.gsmworld.com/roaming/gsminfo/cou_gb.shtml

10. **Planning assumptions, 2006**. CCS, Cabinet Office. Published as Generic Challenges to Business Continuity at: http://www.pfe.gov.uk/business/generic_challenges/index.shtm .

11. **Ensuring resilient telecommunications.** A Note by the Civil Contingencies Secretariat. March 2006.

12. **Outsourcing: Security Governance Framework for IT Managed Service Provision, Policy and Best Practice**. Id. 00524 . NISCC. August 2006. Available at http://www.niscc.gov.uk.

13. **Federation of Communications Services** is the trade association and the representative body for the mobile and telecommunication services industry in the British Isles. Visit them at www.fcs.org.uk.

14. **RAYNET,** the Radio Amateurs' Emergency Network, is the UK's national voluntary communications service provided for the community by licensed radio amateurs. Visit them at www.raynet-uk.net.

15. **Digital Project Report, PMR Technology Appendix V1.0**. Radiocommunications Agency. Download a copy at http://www.ofcom.org.uk/static/archive/ra/topics/pbr/digital/index.htm.

What's new

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Version 9.8. Comments following review by TIDO(SD).
Version 9.7. For posting on www.ukresilience.info.
Version 9.6. Interoperability considerations (see para 9).
Version 9.5. Internal and selected external review complete. Circulated to attendees of the Stakeholder Workshop for comment (29 September, 2006).