TELECOMMUNICATIONS SUPPORTING SIGNALLING AND RAILWAY OPERATIONS

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INTRODUCTION

Telecommunications and Signalling have a long relationship in the history of Railway Engineering. Signalling systems have a vital need for telecommunications which can be viewed as providing the arteries for both connectivity and information flow. Without telecommunications, capability of signalling systems would be reduced leading to the operational railway being unable to operate normally i.e. user expectations would not be met. As such, telecommunications is a fundamental component of signalling systems – both today and tomorrow.

Communication enables signallers to keep in touch with each other, and with the over-seeing "control" which determines the priority of passage of trains. When there are problems, drivers need to be able to speak to the signallers to summon assistance or to get round equipment failures. The introduction of radio systems offers instant communication to the driver, enabling the driver to be warned of impending danger even before the signalling system can provide a warning. Remote control of signalling equipment needs communication channels to transfer the data. Looking to the future, this will become even more important as radio based signalling systems depend upon the communications medium to keep trains running. Signalling and telecommunications remain closely allied technologies.

This paper seeks to set out how telecommunications supports signalling systems and the operational railway. The paper also considers telecommunication developments occurring on the railway and what this will provide for signalling.

For ease, this paper has been divided into two broad sections: the railway communications network which provides the core on which specific applications, and others depend, and then the railway specific applications of telecoms technology that support the operational railway.

RAILWAY TELECOMS NETWORK

The basic building blocks of the railway telecoms network are:

- the lineside copper cable distribution systems
- trunk (fibre optic) cable for long distance transmission
- transmission systems
- internal telephone network
- data networks

Lineside cable distribution

Even today, for the majority of purposes the final connection to equipment is carried over copper cable pairs. This necessitates a lineside copper cable distribution system with access cabinets at, typically, 500m intervals and at all key locations like equipment rooms. In rural areas these copper cables may be shared between signalling and telecoms usage, which necessitates the telecoms technician taking precautions akin to signalling technicians to protect safety critical circuits from inadvertent interference. This is an important distinction between public networks and railway ones: railway technicians require additional training and competencies to cover these risk mitigations.

Transmission Networks

Standard public telecoms transmission equipment is utilised to carry audio circuits and data over longer distances. Synchronous Digital Hierarchy (SDH) systems have been deployed and the Fixed Telecoms Network currently being deployed by Network Rail will replace this with a national SDH network controlled from the Telecoms Engineering Centre (TEC) at Stoke.

Fixed Telecoms Network (FTN) will replace ageing legacy transmission systems and carry Global System for Mobile communication – Railways (GSM-R) traffic between radio base stations and switching centres. GSM-R is being deployed by Network Rail to replace obsolete radio systems such as NRN and CSR.

Both projects are self provision funded via the Regulatory Asset Base and Track Access Charges. A single National Telecoms Project team was created by Network Rail to deliver both projects as the two projects are intrinsically linked i.e. GSM-R is dependent on the fixed network to deliver GSM-R traffic within the system.

Direct contracts with equipment suppliers and installation contractors were established. Network Rail control the design of the systems and integration risks.

The FTN/GSM-R project represents over a £1bn investment in infrastructure controlled by Network Rail. Installation began in 2003 with scheduled completion in 2015.

Fixed Telecoms Network (FTN) currently being deployed will replace existing transmission systems with a national SDH network controlled from the TEC, and will monitor the condition of the network, and see the majority of network faults before the user does. The TEC will keep all records and allocations, and will manage the provision of new circuits, ensuring that the design criteria for each are maintained. For example, a remote SSI circuit has a timing restriction that limits the number of links it may be routed through. The TEC will control this.

The network is based on a ring structure, giving very high availability. Circuits are automatically re-routed around failures. The network will reach all 16,000kms of the railway and will link all control sites with either a fibre optic connection or a digital link supported on a copper cable.

The transmission is based on the international Synchronous Digital Hierarchy standard, known as SDH. SDH is very flexible, new connections can easily be made, and additional capacity can be provided when required. It has been successfully used in many railways. Sophisticated network management facilities give a radical improvement in the management of the network. This enables fast recovery from failures, most of which can be accommodated without affecting service to the end user. SDH allows for great flexibility, being scalable and adaptable to the future requirements of the railway.

The technology increases the available capacity whilst reducing the amount of equipment in the network. It will be far more reliable and much cheaper to run than the existing mix of transmission arrangements or buying in of services from third party operators which incur an ongoing rental charge i.e. an operating expenditure cost.

Once FTN has been fully installed and commissioned, it will have sufficient capacity to carry the following existing and future services:

- GSM-R
- Electrification controls
- Signalling bearer circuits
- Operational and business telephones
- Existing radio systems
- IT wide area network

The deployment of a national SDH network will enable Network Rail to move forward to an Internet Protocol (IP) enabled communications network as any IP network development will exploit FTN cables (fibres), routes and equipment locations. It is clear that there are advantages from deploying IP based networks so that data packets can be routed according to system utilisation rather than follow any fixed routing specified. These systems will also provide flexible approaches to connecting new telecoms and signalling equipment into single converged networks that have the ability to handle different types of data and their differing requirements for transferring across a network - such requirements being specified through quality of service (QoS) parameters.

Internal Telephone Network

Under the railway privatisation process of 1994, the ex-BR network of telephone exchanges were taken over by a third party provider (Global Crossing) rather than being part of the infrastructure controller’s assets. At that time it consisted of a large number of first and second generation electronic switches and a few Strowger type electro-mechanical exchanges; investment by Global Crossing saw this replaced by a modern network linking all office and operational accommodation and provided a few specialised facilities for railways.

(i) The 999 service - One of the issues with calling out emergency services is the need to ensure that the correct civil emergency service “control” room is contacted. Whilst this is simple to organise for the public telecoms operator who knows where every connected phone is situated, this is a problem where an extended internal network is provided. In Railway telephony, for example, most of the Salisbury to Exeter line is connected to one of two exchanges, despite the fact that it passes through at least three different counties. To ensure that the call is sent to the correct civil emergency service control room, a “999” call from a railway internal phone is first directed to a railway emergency operator, who uses the incoming call identity to forward the call to the correct control room. It is essential that a database is maintained to identify specific telephones against the relevant emergency services.

(ii) Short Code dialling to ECRs - This essential facility arises out of the need to provide an easy way to communicate with the electrical control room in an emergency. Each of the electrical control rooms is assigned a three digit code in the series 17x, and by dialling that code on any telephone anywhere in the geographic area of control of that ECR, the call is connected to an emergency incoming call line at the ECR. This allows the operator to take the call and deal with the emergency promptly. In telecoms design terms, this requires that the PABX network be designed to allow for alternate routing between exchanges and to minimise risk of these emergency calls failing owing to network congestion. .

Protection of the Network against Traction Interference

A major issue for the provision of an internal telecommunications network is the EMI inducing effect of the traction currents associated with the electrified railway. This is primarily true on the AC electrified railway where interference occurs because the traction power system (which depends upon the rails for the return current path) is effectively an earth return system as the current leaks out of the return rails either side of the train. The current flow from feeder point to train can be looked upon as the primary side of a transformer, with the telecoms cable circuit the secondary. Although the mutual inductance is small, the lengths of parallelism and the traction currents are such that standing voltages can be measured of up to 60V on lineside copper cable pairs, and these voltages need to be monitored and kept below this limit for the safety of staff working on the cables. These voltages also introduce noise onto the receiver of the audio signals, appearing as audible noise in the background of telephones and affecting the signal to noise ratio for data communications. Elaborate protection systems have been devised, which are outside the scope of this short introduction to railway telecoms. The introduction of fibre optic based transmission does, therefore, provide a significant advantage in railway telecoms applications; as not only is the quality and bandwidth much improved, but noise immunity and staff safety are assured.

OPERATIONAL TELECOMS SYSTEMS

Signal Post Telephone (SPT) Systems

Railway operation requires that a driver who has stopped a train at a red signal must communicate with the signaller after a short time. In the event of a signal failure, the signaller may personally instruct the driver to proceed past the red signal. Also when planned engineering work requires a temporary or permanent blockage of the line, the person in charge must arrange this directly with the signaller in charge of the section of line. Other than when the driver or technician can walk to the signal box, this demands a reliable telephone link. The signaller must be able to do more than just speak to the caller: the signaller must also be able to understand exactly where the caller is speaking from, so that the necessary instructions can be given to the right person, and only to the right person. This places extra safety requirements on the communication system: a high integrity identification of the calling line and the minimisation of risk of overhearing. Whilst modern electronic PABXs are able to forward the calling line identity, this requirement predates the availability of modern digital PABX technology and many elaborate systems have been developed to give this additional security.

In its simplest form, the SPT system consists of a central battery (CB) or battery ringing (magneto) telephone connected via a dedicated pair of copper wires to an individual telephone at the signal box. The signaller knows positively where the caller is located based upon which telephone is ringing. However, beyond a few such telephones the system becomes unmanageable!

Since a signaller can only talk to one caller at a time it makes sense to concentrate the circuits onto one telephone for the signaller, at the same time providing a secure indication to show which circuit is connected. Such a device is known as a Signal Post Telephone concentrator. Termination at the signal box end could be to a matrix of individual keyswitches/pushbuttons for each signaller's position or to a visual display indicating the number of the calling telephone and a single answer button.

Small, bespoke systems such as STS Intertec Concept 32 are considerably cheaper to provide than digital PABX and are in widespread use today in the small to medium sized signalboxes. This product was first designed to a BR specification and is manufactured almost solely for Network Rail. Unlike office telephony systems, this has meant that there is stability in the design, giving an extended working life in a market where obsolescence normally determines renewal decisions. Standardisation on a limited selection of equipment is now the aim, to reduce spares holding, training requirements and hence operational costs.

SPT systems for larger signalboxes have either been bespoke electronic systems or based on Commercial off the Shelf (COTS) PABX equipment. To achieve this economically, and to improve availability, remote concentrators or nodes are provided at the point where copper cable circuits combine, and a limited number of transmission channels are then required to connect the remote node back to the signal box. These systems often permit alternate routing or diversity between the remote node and the signal box, which boosts availability.

Large signalboxes - particularly IECCs - have so many signals controlled by one signaller that panels providing individual keyswitches/pushbuttons for each phone are impractical. This has led to the adoption of VDU based solutions with multiple screens displaying the different telephones available. This technology originated in the city banking dealer rooms, but is now commonly available on PABX based solutions. The technology used also supports "light duty" working in signalboxes, where control of two signallers' areas can be combined onto one operating position when the number of train movements is reduced (e.g. nightshifts and Sunday working).

PABX based systems are based on a standard telephone exchange, but software modifications or rigorous design controls are necessary to disable many of the features, most notably the conference bridge, which if used in the railway application could have disastrous consequences. It has also been necessary to modify some line interface cards to ensure that they can cope with the hostile railway EMC environment. These changes tend to reduce the advantage of using COTS equipment, and in addition the PABX solution as an SPT system has proved rather expensive to run, owing to the necessity of upgrading software to the manufacturer's latest build standard driven by other commercial needs, not those of railway operations.

Electrification Telephones

Communication from the lineside to Electric Control Rooms (ECRs) is another vital operating and safety facility. There are slightly different requirements depending upon whether the electrification system is 3rd rail DC or overhead 25kV AC.

On AC overhead electrification systems communication facilities are required to allow emergency disconnections and to control planned isolation arrangements. Telephones (or historically 'plug points') are provided at regular intervals of approximately 1km at the trackside. Telephones are also provided at feeder stations, track sectioning cabins and at neutral sections.

On DC 3rd rail systems, where there is the additional hazard of passengers falling from station platforms, emergency telephones are provided on each platform, as well as the many feeder stations and track paralleling huts. However, the requirement for lineside communications is dispensed with because the traction power supply can be disconnected in an emergency by dropping a short circuiting bar from the return rails onto the live rail; equipment to do this is carried in each train.

Electrification telephones developed as bespoke systems for the railway and several solutions emerged over the years. All were based on omnibus circuits, that is numerous telephones connected across a single pair of wires. These omnibus circuits went through various innovative developments to improve both facilities and efficiency over the basic design of code ringing from battery-powered telephones. However, these systems required intensive maintenance and were intolerant of faults, so they have gradually been replaced with telephones connected to the railway internal telephone network, with standard short code dialling to get to each electrical control room without having to resort to local and/or trunk dialling codes. The PABX network thus provides fault tolerance because calls can be re-routed around congested or failed routes.

In the Electrical Control Rooms a basic telephone concentrator, such as that provided for signal boxes, can also be employed to allow the controller to select which call to answer. Emergency and general purpose numbers are provided, plus outgoing only lines for emergency calls from the controllers and direct connection to the PSTN to provide fault tolerance. Some key locations such as major signalboxes are provided with direct links for speed of connection. One important difference between the SPT concentrator and the ECR system is that in the ECR, conference calls are permitted so that more than one controller can hear an emergency incoming call and also so that the controller can speak to more than one location whilst handling an emergency.

Level Crossing Communications

Whenever road vehicles or pedestrians require to cross a railway line, a key requirement for the safety of the users is the ability to communicate with the signaller. In some cases, the crossing may be operated automatically by the signalling system with no need for the signaller to be able to see what is going on, so the only way of drawing the signaller's attention to an incident at the crossing is by using the telephone. In others, the use of the telephone represents the only means of ascertaining whether the line is safe to cross. In both of these cases, the systems must have high availability; and the same requirement exists as for an SPT system about the identity of incoming calls.

At level crossings on public roads, it is a statutory requirement to provide telephone communication to the nearest signal box, except where the box is immediately adjacent. The telephones are provided for public road users, and thus have to be usable by untrained operators. This means providing a system that is simple to use, is not disabled by incorrect use or by misuse, and is reasonably resistant to vandalism.

For automatically operated crossings this has led to a number of requirements being set. These include:

- Up to six telephones at a crossing sharing one line.
- Continued operation if one of the handsets is left off-hook or vandalised.
- Monitoring of the availability of the equipment with an alarm condition if the circuit from signal box to level crossing has become defective.
- Status reporting at the controlling signal box.
- Transfer of calls from the crossing to the next signal box when normal controlling signal box closes but the line remains open.
- Easy application of recorded message if line closes.

These requirements are met by a special design of equipment known as PETS – Public Emergency Telephone System. There is, in effect, a local telephone concentrator at the crossing handling up to six local phones which are then connected to the controlling signal box over a single channel. This can operate over a copper cable or a transmission channel. Monitoring of the line is achieved by periodically sending out an interrogation code and the response both confirms the availability of the line and reports status of the equipment at the crossing. The system requires a power supply at both signal box and crossing with battery back-up for power failure conditions, but since the signalling equipment also requires power, this is not a practical limitation. The system has near universal application at AHBC and other public road crossings.

For farm crossings and minor access roads to private property, the safety integrity required of the communication link can be lower, and this can be achieved with a system similar to the SPT system. In remote rural areas and on branch lines there may be no railway cable at the trackside, and in these circumstances a BT circuit is often employed. In the majority of these installations a standard CB telephone is provided; when the phone is taken off-hook the BT exchange equipment automatically connects the caller to a pre-determined line at the controlling signalbox. Since these lines are part of the public telephone network, an irritating problem experienced was the receipt of “cold calling” telephone sales calls and to guard against this, the lines involved were put into a closed user group (effectively a Virtual Private Network, or VPN) so that only phones within the group can call each other. Another problem was BT’s introduction of automatic line testing on these phones; the short test of the line normally doesn’t disturb private users but the sensitive equipment used at the controlling signalbox detects the call and maintains the ringing even after the BT equipment has completed the test. This nuisance feature required a redesign of the equipment used at the signalbox.

Radio Communication

The benefits to railway operations from the use of radio are immediately apparent. The requirement for the driver to leave the cab and get down to ground level in order to use the telephone introduces delay and is unpleasant for the driver in adverse weather conditions. It can also be dangerous, as was demonstrated in 1997 when a driver was struck by another train and killed whilst using the SPT. Furthermore, the ability to set up communication between signaller and driver in an emergency wherever the train is located has safety benefits, whether for telling the signaller about an incident on the line or warning a driver to stop in an emergency. Currently two main systems are in use on Network Rail: the NRN and CSR; these are going to be replaced by GSM-R.

National Radio Network (NRN) - The origins of NRN predate public mobile telephony - it was borne out of the desire to improve communications to mobile workers. The original requirement of the NRN was to (i) communicate the management of line possessions more efficiently and (ii) permit the elimination of electrification telephones on AC overhead electrified lines. The first installations were delivered using radio equipment operating in Band II (105 and 138 MHz) with interconnections facilitated by a radio operator; the network was re-engineered into Band III (200 MHz) from 1984 onwards with the facility for automatic call connection between users (and between users and the internal telephone network).

A tragic railway accident at Polmont in 1983 was caused by a train hitting a cow on the line. A previous train had seen the animal but the driver had no opportunity to warn the signaller so that precautions could be put in place. A major recommendation from the ensuing inquiry was to adapt the NRN to provide emergency communications from train to signallers. This was developed as an overlay to the NRN and the extra features this provides are still known as the Overlay Radio Network (ORN). The extra features are basically the ability to press a red emergency button on the radio in the train cab, which will seize any available radio channel and if one is not available, will disconnect an existing call and then seize that channel.

The NRN/ORN network consists of 22 radio areas each with a control centre supporting up to 40 fixed (base) stations, four railway telephone network connection lines, six direct lines to Electric Control Rooms, one line to the Emergency (999) Operator and two interfaces for monitoring and fault reporting purposes. The system conforms to MPT 1327 specification for trunked Band III radio networks.

Full interconnection with the Railway Telephone network is provided in both directions, also a radio-to-radio connection facility. Each radio control area has its own unique trunk access number from the telephone network, in effect making each radio control a ‘network zone’. Radios are given a 4-digit number.

The NRN is a track to train radio system but it is not considered a secure system, since there is no correlation between the radio call number and the train description, nor does the system offer a direct connection from train radio to signal box, this only being achievable by an interconnection with the telephone network. NRN was not designed for the passing of safety critical operational messages, but it is recognised that this does happen where the SPT is in a potentially unsafe location by the driver dialling the telephone number for the controlling signalbox.

In line with government plans for NRN frequencies to be reallocated to HD television broadcasts, the operational radio license for the NRN expires at end of 2012 for southern England (i.e. south of the ‘Severn Estuary / Wash line’) and in December 2015 for the remainder of the British Isles.

Cab Secure Radio (CSR) – CSR which operates in the UHF band at approx 450MHz, offers a train driver secure communication to the signaller from the cab thus negating the need to leave the cab and use trackside phone to communicate to the signaller.

An essential requirement for this system is that when the driver calls the signaller, the signaller can identify exactly which train the call is coming from. In British practice, trains are known by their "headcode" in the format 1A11. Each radio unit in a cab has a unique identity, but this has got to be linked to the headcode if it is to mean anything to the signaller. To achieve this, at the start of every journey the driver must register the train onto the CSR system so that the unique radio number can be matched to the headcode for the particular service that the train is then operating. As this system evolved in the early 1980s, it was not possible to provide the drivers with an alphanumeric keyboard with which to input the headcode of their train; a simple numeric keypad was provided and the "set-up" procedure required the driver to input the signal number at which the train was positioned. The CSR system then interrogated the train describer computer to establish which headcode was located at the signal number input by the driver, and then associated that headcode with the radio number. The headcode is sent to the driver as a confirmation.

A major requirement is an emergency call facility from the train, which allows immediate contact with the signaller even when he/she is already engaged in another call. A general call facility is also considered essential. This enables the signaller to speak to all trains simultaneously and warn drivers of hazards, causes of delays and other information of common interest. The general call can therefore be used in an emergency situation.

Additionally, onwards speech connection to the telephone network is normally provided to allow the driver to speak to maintenance staff and obtain advice in the event of train failure or other operational problem. The connection is under the control of the signaller. Recording takes place of all speech conversations and data exchanges for verification purposes in the event of an incident.

The ability to send data messages in place of speech to advise, for instance, that the train is standing at a signal helps save the signaller time. Provision is made for a connection from the signaller to the train's public address system for use in the event of the driver being incapacitated.

The CSR system is in use around London and South East, London to Rugby and Liverpool. The same basic design of system is used for the Channel Tunnel with some modifications to deal with the different train numbering concept.

GSM-R - As mentioned earlier in this paper**,** Network Rail is currently implementing a new train radio system to replace CSR and NRN, using the European EIRENE specification. This will provide for the first time direct signaller to driver communications systems across the entire network, giving performance and safety benefits. The GSM-R system was developed through the UIC against a specification and through trials; the specification is known as EIRENE, although strictly this was the name of the trial project.

The choice of GSM-R has been dictated partly by EU directives, which require interoperable equipment to be provided on high speed and conventional TENS routes in Europe. However, there are also strategic benefits from selecting an European-wide standard system, as the development costs for rail specific needs are shared, and the market share represented by the entire European rail network is more significant to the radio equipment manufacturers.

GSM-R is a development of the standard second generation mobile telephony systems, utilising a dedicated part of the radio spectrum allocated to rail usage throughout Europe (876 - 880 MHz and 921 - 925 MHz). Two suppliers were chosen to develop GSM-R products for the network - Siemens (cab mobile) and Nortel (core radio network infrastructure); the Nortel GSM-R radio business later being sold to Kapsch. In addition to the cab and core radio infrastructure equipment, Frequentis supply the signaller's terminal used for making and receiving calls to and from trains.

The main differences between public GSM and the railway application GSM-R are the addition of facilities such as group calls, voice broadcast, location based connections, and call pre-emption in case of an emergency. Location based calls enable a train driver to dial a specific code to be connected direct to the controlling signaller for the section of line the train is located on; call pre-emption ensures that emergency calls can be made when the network is busy by removing lower priority traffic. The usage of a dedicated network (rather than public networks) is essential to ensure control over continuity of supply - the disruption to public networks caused during major incidents (e.g. July 2005 London bombings, or any major sports event or traffic disruption) demonstrates why this is important.

The network design consists of about 2,500 trackside base stations served by about 10 base station controllers together with two mobile switching centres arranged to provide disaster recovery facility in the event of catastrophic failure. A switching arrangement will provide connections to about 1000 fixed terminals, located in all signal boxes, route controls and ECRs. Facilities will be provided for central voice and call data recording.

GSM-R is important not only because it provides a standard product for train radio voice communications, but also because it provides the bearer for the ERTMS signalling systems. There is currently much debate regarding the technique chosen for this: the ERTMS systems currently deployed use “circuit switched” solutions which effectively use the GSM-R as the bearer of a point to point telephone call over which modems exchange data (similar to dial-up internet access). As ERTMS data is not exchanged continuously, this is actually wasteful of the radio resources employed. The technically preferred solution is to use packet switched data, using GPRS techniques. This allows more data to be exchanged over one GSM-R cell. However, it requires more development of the ERTMS product and it’s associated European interoperability standards to use this. A European project has now been initiated that will develop the concept of ETCS over GPRS (packet switching) and demonstrate this concept in the field with prototype ETCS equipment. The output of this project will be robust European specifications that support ETCS over GPRS implementation.

In summary the Network Rail GSM-R will provide:

- Main switching centres
- Over 2,500 radio sites (with transmission access nodes)
- 500 standalone transmission access nodes
- New train radio in 9,000 driving cabs
- New radio terminal for every signaller’s position
- New operating rules
- Training for signallers and train drivers using simulators

Driver Only Operation (DOO) CCTV Systems

One particular requirement which emerges from the desire to remove the conductor from a train is the provision of a safe system for viewing the train doors. The driver must be able to determine both (a) when it is safe to close the doors; and (b) whether once the doors are closed, anybody is trapped by the doors. The sliding doors on a DOO train are designed to detect if a limb or some other body part is trapped in the door; however, the detection mechanism cannot detect something smaller. It is essential therefore, that the driver can check each train door after it has been closed to make sure that nothing is trapped. Examples can include dog owners holding a dog on a lead; parents holding children on reigns, and people trapped by jacket flaps or scarves. Although this may seem unlikely, it can happen, and at least one fatality has occurred on London Underground where a person trapped by clothing jammed in a door was dragged along by the train and fatally injured.

This requires that cameras are fixed along the station platform so that images can be displayed to the driver on monitor screens. On dead straight platforms a mirror can replace the cameras and monitors. The greatest safety issue with either solution is that the image size must be big enough for the driver to see anything that is trapped without introducing excessive cost when building and maintaining the system. Given the variability of eyesight of drivers, this presents a few challenges!

Maintenance becomes vital since the alignment of the various cameras must ensure that there are no coverage gaps. On London Underground there are markers provided along the station platform (look for the diamonds in the yellow line at the platform edge!); at present on Network Rail this has not been implemented.

Developments have included (a) replacement of the CRT based monitors with backlit TFTs; and (b) the fitting of miniature cameras on the side of new rolling stock connected to monitors in the driver’s cab, so enabling the driver to view all doors (even when multiple unit operation takes place). The advantage of the latter is that it permits DOO operation anywhere the train can operate provided the other requirements (principally over radio) can be met.

DOO CCTV systems deployed on London Underground include the use of in-cab DOO CCTV displays. In this application, pictures from fixed platform infrastructure cameras are transmitted wirelessly to a display within the train cab.

Customer Information Systems

In the area of Customer Information Systems (CIS) there is a dependency on Signalling to provide Telecoms with information. CIS systems are used on the railway to provide train running information to passengers at stations. Train movement or TD data from Signalling Train Describers (TDs) is fed into CIS systems where it is then compared with the published train timetable to forecast how a train running with respect to its scheduled time. This output is then provided to passengers via CIS displays.

The TD, is a processor system that takes data from the various signalling equipment (signals, points and track) and makes that data available in various forms elsewhere. The stream of data from the signalling equipment essentially tells the TD when trains are passing over which track circuits i.e. when they enter (or leave) particular signal berths. The outputs from a TD are passed not only to CIS systems, but also to Signaller’s display equipment to show where trains are.

The disadvantage of CIS systems fed from TD data is that the information is not real-time in that granularity is insufficient. Train movement data is essentially driven from track circuits that do not provide accurate location data for a train. Future advancements in this area will see CIS dependency on location data shifting away from signalling TDs to Global Positioning Systems (GPS).

Dedicated Links and Open Networks

Signalling systems have tended to use dedicated point-to-point copper links, with the notable exceptions of time-division multiplex (TDM) and remote SSI links. Dedicated links are expensive, inflexible and often have limited or no resilience against failure.

The use of open telecom systems such as FTN, reduces the need for expensive dedicated links. By sharing capacity in telecoms systems the cost of signalling data becomes marginal. The number of copper cores required is dramatically reduced, giving savings in installation and maintenance costs for copper cables and cable routes. In recent years the rising trend of cable thefts because of increased copper prices and the subsequent impact on train performance when the cables are stolen, is a strong reason to reduce the number of copper cables where possible through replacement with FTN fibre. Generally, performance and reliability is radically improved because modern telecom networks are highly reliable, being arranged in rings to minimise single mode failures, and with automatic re-routing around failures. However moving to open networks means that safety integrity must be provided by the signalling application rather than the telecoms transport mechanism.

Therefore for signalling systems to take maximum advantage of telecoms networks, as much as possible signalling systems should be designed to be compatible with open systems. Future signalling circuits need to be compatible with ITU-T international telecoms standards, and with the categories of transmission systems and defence approaches set out in BS EN 50159:2010 Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems.

CONCLUSIONS

Telecommunications is a fundamental component of signalling systems both on today's and tomorrow's railway. The close relationship between Telecommunications and Signalling brings business benefits for the railway. Use of Telecommunications systems is invaluable when signalling systems fail as they enable railway operations to run train services using communication and operational rules.

A range of safety related services and operational systems are provided by Telecoms which support the running of the operational railway. Some of these systems require networks for connectivity and transfer of data. These networks are shared at present to only a small extent with certain signalling applications.

With FTN and GSM-R systems being rolled out, Network Rail is renewing its existing transmission and radio systems with systems that will cater for today and tomorrow. FTN will be the fixed bearer network that will support many applications across Network Rail including signalling. However to take maximum advantage of this network, signalling systems will need to adapt as much as possible to using open transmission networks. This will mean that safety integrity must be provided by the application rather than the transport mechanism.

As GSM-R is the current bearer network for ERTMS Level 2 and Level 3, the close relationship between Telecommunications and Signalling will continue for some considerable time into the future.

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