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GLOSSARY OF TERMS

ATM: Asynchronous Transfer Mode – normally refers to equipment or standards that use this type of communications standard. It is a standard used for communication backbones that carry multimedia at the highest of bandwidths applicable.

Blasts: The actual explosion that breaks the rock at thee mining face

Box: The storage cavity developed in the rock for the storage of mined rock. The Horizontal Transport locomotives normally pick up rock from the boxes and deliver this to the tips near the shaft.

BU: Business Unit

C&I: Control and Instrumentation

Chute: The Control device used to control rock flow from an aperture like the discharge hole of a box. Normally a mechanically operated blade that can stop the flow of the rock.

CIC: Control, Instrumentation and Communications – Normally refers to the discipline of professionals, or equipment of this type.

COS: Class of Service

Cross-Cut: The off shoot of the main haulage which approaches the ore body (reef plane). It is essentially a tunnel peeling off the main haulage.

FDDI: Fibre Distributed Data Interface. Similar to ATM, this refers to equipment or standards of this type.

Haulage: The main tunnelling leading away form the shaft towards the working areas underground.

I/O: Input/Output. Typically refers to inputs and outputs of a system.

Leaky feeder: A Radio Technology that uses a type of co-axial cable with an intentionally leaky outer shield. This allows the RF signal to radiate out evenly over the entire length of the run of cable.

Legacy: Normally refers to a system that is catered for because it does not make financial sense to re-engineer it, but it is not the ideal system for the long term technology vision.

LHD: Load Haul Dumper – A heavy trackless vehicle used underground for the transport of rock.

Loco: Locomotive – The traction engine (normally battery driven) used underground to pull trains of **material cars** or **rock hoppers**.

Mining Team: The team of workers in a stope, normally consisting of a team leader, mining assistant, drilling team (about 4 drillers) and support team (about 4 support persons).

Mobile Communications Domain: One of the communications domains defined to rationalise communications systems and apply communications technology optimally. Essentially this is the radio transmission domain.

MRS: Mine Radio Systems – a company dealt with in the compilation of this dissertation.

Ore: Gold bearing rock

OTN: Open Transport Network. A phrase primarily used by Siemens for their multi interface dual redundant fibre optic system.

Panels: The working face. Typically the face in a stope area that gets successively blasted to produce the ore for transportation to the plant.

PDA: Personal Data Assistant – a 'Palm Top' PC which has facility for appropriate data entry and retrieval. The vision is that this should be continually on line to the network by RF technology.

PLC: Programmable Logic Controller – the microprocessor device wired to inputs and outputs in the plant for the purpose of controlling or monitoring such plant

Process Control Domain: One of the communications domains defined to rationalise communications systems and apply communications technology optimally.

Reef: The body of ground containing the gold bearing material. Normally a slab of ground about 70cm thick and sloping at 30 degrees to the horizontal.

RF: Radio Frequency

Rugged Medium Domain: One of the communications domains defined to rationalise communications systems and apply communications technology optimally

SCADA: Supervisory, Control and Data Acquisition – The PC software system used to monitor, display, trend, alarm and do high level control upon plant via a network of PLC inputs or remote inputs.

SDH: Synchronous Data Hierarchy. Similar to ATM, this refers to technology or standards of this type.

Shaft: The main access holes to go down underground. There can be sets of two shafts (one for ventilation feed and one for ventilation extraction) reaching their maximum depths underground, then feeding sub-shafts reaching further. The winding conveyances run in guides down these shafts.

Shaft Domain: One of the communications domains defined to rationalise communications systems and apply communications technology optimally

Stations: The off-loading and on-loading area at each level at the shaft.

Stope: The working area where the reef is mined.

Support: The packs or props used to support the roof in a stope and stop it from collapsing.

TCP/IP: The converging internet/network standard in the transport and network layers of the 7 layer OSI model.

Waste: Rock with no gold in it. Normally generated from developing tunnels to access the ore body.

APPENDICES

A. 1. FDDI, SDH AND ATM TECHNICAL INFORMATION

The section attempts to extract the more important technical points around these broadband standards. Most information is taken from the following references as listed in the References section: "Fred Halsall; "Data Communication Networks and open System Standards"; " - [19], and "John F. Mazzaferro; "FDDI vs. ATM - High Speed Networks"; Computer Technology Research Group; Charlestown, South Carolina, USA; First Edition, 1994, " - [21]

FDDI II and SDH are synchronous networks providing dedicated/independent channels to the multi-media sources requesting service. ATM is a cell based asynchronous technology providing dynamic service flexibly to the sources no matter what media the source is. They can almost be considered in two different leagues but these are the dominant technologies seen currently in the market for Broadband services.

A.1.1 FDDI

FDDI initially was a data orientated network synchronous technology. FDDI II has been developed to cope with the constant data delivery required of isosynchronous data (data generated at a constant bit rate and requiring delivery at a constant bit rate). This is typically the type of service required of voice and video traffic. When FDDI II is operating in hybrid mode then the 100Mbps bandwidth is divided in channels controlled by the cycle master. Repetitive data string cycle are generated every 125μs (equivalent to the basic sampling interval for the digitisation of analogue speech. All stations synchronise by means of a 20 bit synchronisation pattern at the start of each cycle.

A.1.1.1 SDH (Synchronous Digital Hierarchy)

SDH was initially developed by Bellcore in the USA under the title SONET (Synchronous Optical Network).

The basic transmission rate is 155.52 Mbps called STM-1 (Synchronous Transport Module level 1 – abbreviated to 155Mbps). Higher rates are implemented in multiples of SMT-1, such as SMT-4 (622Mbps) and SMT-16 (2.4Gbps). In SONET the basic rate is 51.84Mbps (a third of STM-1)

Again the SDH consists of a repetitive set of frames every 125µs (digitised voice aligned). SDH equipment has software with it known as a Network Management (NM) Agent allowing diagnostic information flow. Remote station configuration allows channels to be assigned and configured by the NM software.

Dual Fibre rings are typically used to set up redundant paths in case of system segment failure.

Siemens OTN (Open Transport Network) is a proprietary product with synchronous dual counter rotating rings very similar to SDH. The latest versions of OTN are available with SDH compliant cards, however higher stack level standardisation is required before true vendor independent interoperability can be achieved with OTN.

A.1.1.2 ATM

The main advantage of ATM is that it can dynamically deliver bandwidth as asked for by service requesting stations. It can support both connection orientated and connectionless traffic on the network. Its traffic management features are well suited to more complex Networks requiring switching together with support for connection orientated traffic. It has more flexible but more complex traffic control with the ability to manage the traffic on the network to the limits of the bandwidth. The small cell size also supports multimedia traffic better. The standard (as the name implies) is Asynchronous meaning it that individual bits in a cell are synchronised but timing between cells can vary, this being a consequence of the more dynamic nature ATM brings to traffic control.

The Data Link and Physical layer are implemented in cells of 53 bytes long. The first 5 bytes are the cell header containing fields for cell routing, traffic flow, cell identification, and error correction. The remaining 48 bytes are for the information payload.

There are essentially 3 ATM layers in the Protocol Architecture:

- ATM Adaptation Layer (AAL)

  Provides the convergence (adaptation) function between the Class of Service (COS) provided to the user and the cell based system underneath. Depending in the COS this layer converts the incoming data into streams of 48 bytes for the lower layer.

  The ATM technology provides essentially 4 types of COS:

  - AAL1: Class A: Constant Bit Rate (CBR) Service

    This is connection orientated, typically required for constant bit rate data length such as voice traffic.

- AAL2: Class B: Variable Bit Rate (VBR) Service

Also connection orientated, but typically for variable bit rate traffic such as compressed video.

- AAL3/4: Class C/D

This is for connectionless traffic, typically data. Previously this was 2 layers with layer 3 intended for connection orientated data traffic, but now this was merged to provide a connectionless service only for data.

- AAL5: Simple and Efficient Adaptation Layer (SEAL)

Very similar to AAL3/4 but with less control field Information (related to convergence, segmentation and reassembly) in the header. This provides a more efficient but connectionless service.

- ATM Layer

This constructs the header information and multiplexes the cells for transmission in the physical layer. It also receives transmission de-multiplexes and relays the cells to the correct AAL protocol.

- Physical Layer

The upper part of the physical layer is the transmission convergence sub-layer and generates the header check sequence an delineation information of the cell boundaries. The lower part of the physical layer is the medium-dependent sub-layer and is concerned with line coding and bit/clock synchronisation.

A. 2. OVERVIEW OF IEEE 802 STANDARDS

The IEEE 802 family of standards is best viewed using Figure 29 taken from [22]

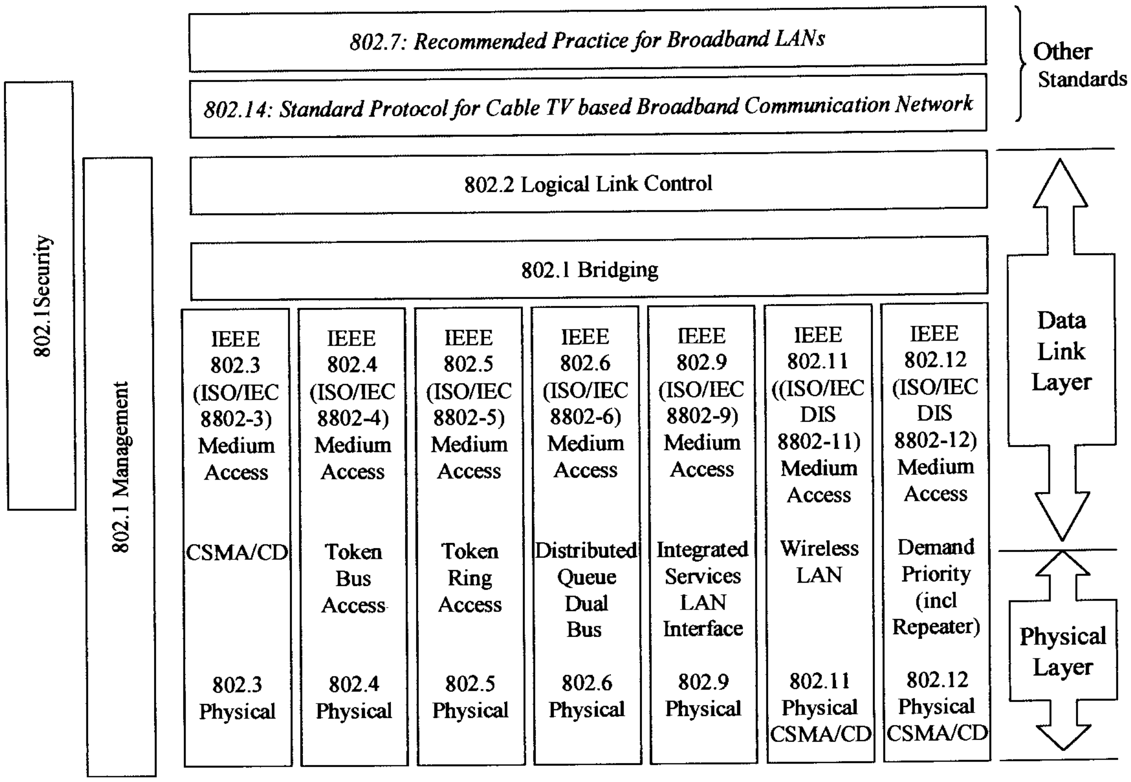

Figure 29: IEEE 802 Family of Standards

Examining the standards in detail is of mainly academic value. Rather we need to appreciate the technical detail that impacts on the use of the standard from a technology management perspective. With that in mind I will only discuss the parts impacting on this project.

A.2.1 IEEE802.3 CMSA/CD Ethernet

This is the dominant Media Access and Physical layer standard found on the Anglogold IT LAN Desktop PC's. The 1993 version of the standard ([23], [24], [25]) was used to determine scope and comprehensiveness of the standard from a technology management perspective. The following points merit discussion:

A.2.1.1 Basic Concepts

CSMA/CD stands for Carrier Sense Multiple Access with Collision Detection. Multiple stations on a common transmission medium use a "busy" detect method to grab hold of the medium when they need to transmit. The stations wait for a quiet period then transmit their data. There is both a "channel free detect" function and a "Collision Detect" function. When the channel free detect within the Data Link layer indicates a free channel, then transmission begins. The frame is formed and all stations read this and determine if the message is addressed to them. If so they pass the message up their ISO level hierarchy. There is a chance that another station can have taken hold of the medium at approximately the same time, in which case a collision in the transmission medium will occur. Collision Detect will notify the Data Link Layer and a Jam sequence of bits will be put on the Transmission medium to ensure no incorrect interpretation of such a faulty message.

A.2.1.2 Architectural Perspectives

The standard cover the Media Access Control (MAC) Sub-layer of the Data Link Layer, and the Physical Layer. For LAN networks there are effectively 4 types of Physical Layer alternatives working on 10Mbps:

- Thin wire coaxial cable with maximum segment length of 200m: 10 Base 2
- Thick wire coaxial cable with maximum segment length of 500m:10 Base 5
- Hub star topology with twisted pair drop cables:10 Base T
- Hub star topology with Optical Fibre drop cables: 10 Base F

Topologies can be implemented in a number of ways but for our purposes star with hub 10Base T, and this is where most Industry product is centred around.

Due to the collision detect method of the standard the station must wait a certain slot time before it can reliably know whether a collision has occurred. This imposes a limitation in the topology since the Slot time that must be waited is just above twice the maximum transmission path delay and this is increased as you go through hubs due to the switching delays with the repeater process. Typically one can go 3 hubs deep in a tree structure.

A.2.2 Fast Ethernet

With the 802.3 specification, the maximum cable length for 10BaseT is 2.5Km. Fast Ethernet reduces this to 100m and with the corresponding maximum signal Propagation delay reduction the data rate is allowed to increase to 100Mbps, called **100BaseT**.

There are two ways to achieve data transfer at this Baud rate, firstly using category 3 cable with 4 pairs reducing the bit rate on each pair to 33.33Mbps – This is called 100Base 4T. Secondly using category 5 twisted pair or optical fibre, and encoding every group of 16 four bit data bits into a 5 bit representations effectively compresses the data into a smaller bit rate. Then using two Pair/fibres transmit this for forward and return Transmission. This is called the **100BaseX** standard.

A.2.3 IEEE802.11 Wireless LAN

Wireless LANs currently on the market use mostly spread spectrum radio or infrared transmission technique. Infrared is more for line of sight applications hence Spread Spectrum RF LAN is more of interest to us.

Two techniques are used for spread spectrum:

- Direct Sequence

  In this technique a pseudorandom code (bit stream) is 'Ored' with the data for transmission. The code bit stream (called the chipping rate) is faster than the data stream. The receiver identifies the code by means of autocorrelation and then synchronises itself for the reception of the coded data, decoding it as it receives it. The amount that the chipping rate is faster than the data bit rate relates to the ability that the RF receiver can identify the data stream and in effect allows the unit to function in a far poorer Signal to Noise Ratio (SNR) environment. The chipping rate to data stream Rate is referred to the Spreading Factor and results in a reception ability gain referred to as the processing gain. From another aspect one can think of the situation as the receiver getting more samples of each data bit the higher the Chipping rate is.

  Each unit operates on a channel allocated via on-line configuration.

- Frequency Hopping

  With frequency hopping the data is sent across the RF medium hopping between the different channels in the spectrum. There is a defined hopping sequence that is tracked by both sender and receiver. An advantage of this method is that problem frequencies can be avoided when encountered.

The IEEE802.11 defines the MAC and PHY layers for spread spectrum direct sequence and frequency hopping, and also for infrared. It creates a framework for Ad-hoc (i.e. a small group of mobile computers) and infrastructure networks (i.e. hardwire LAN replacements). It provides for the co-existence of overlapping wireless LANs and covers authentication and privacy mechanisms.

Another standard to be used for spread spectrum technology specification is the European Standard ETSI 300.328. This standard covers minimum technical characteristics for spread spectrum radio transmission in the 2.4 to 2.4835 GHz range.

- Performance and Coverage Aspects

  Spread spectrum frequency hopping has a lower bandwidth capability than direct sequence technology. This is due to the transition or switching delays in changing between the hop frequencies.

  The Direct Sequence cannot however cope as well as frequency hopping technique in noisy environments. This is due top the **"near far" problem**. With multiple transmitter in the range of a single access point, each transmitter acts effectively as noise for the other's signal. With a very near (hence strong signal) transmitter and a very far one in the range of a single access point, the noise level for the near transmitter swamps the further transmitter's communications.

A. 3. PROFIBUS TECHNICAL DETAIL

Most of the technical diagrams in this section were obtained from the Profibus CD issued publicly.[7]

A.3.1 The Standard

The standard is defined by the European Standard EN 50 170. This covers Profibus as a protocol. The protocol architecture is oriented to the OSI (Open System Interconnection) reference model in accordance with the international standard ISO 7498. It is implemented in 3 forms as described in the diagram below:

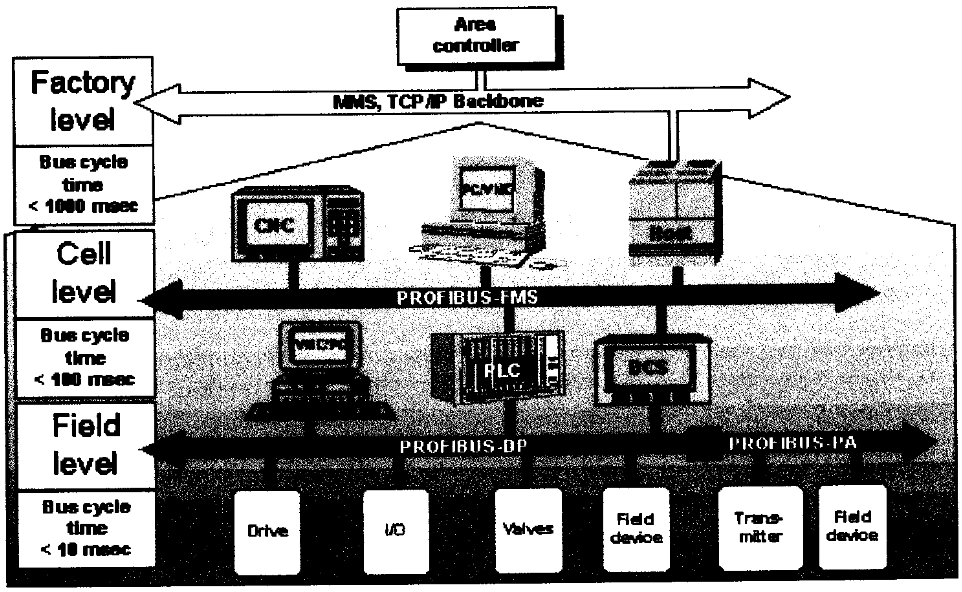

Figure 30: Profibus Protocol Positioning

a. Profibus Field Message Service (FMS)

This is geared for higher end network service providing applications where a high degree of functionality is more important than fast system reaction times. For example uploading or downloading of high volume data, and network configuration management. In PROFIBUS-FMS, layers 1, 2 and 7 are defined. The application layer consists of FMS (Fieldbus Message Specification) and LLI (Lower Layer Interface). FMS contains the application protocol and provides the user with a wide selection of powerful communication services. LLI implements the various communication relationships and provides FMS with device-independent access to layer 2. The bus cycle times are in the order of 100ms. This implements Peer-to-Peer Communications ability as opposed to the Master Slave architecture in Profibus DP described below. Typical transmission speeds between 9.6 Kbit/sec and 12 Mbit/sec can be selected.

b. Profibus (DP)

This is geared for factory automation purposes primarily to provide a 'plug and play' environment at field level (i.e. where one can just plug in a device and it configures right away with minimum configuration to integrate into the bus network). PROFIBUS-DP uses layers 1 and 2, and the user interface. Layers 3 to 7 are not defined. This streamlined architecture ensures fast and efficient data transmission. Most bus type protocols use similar layers not requiring higher level network and connection features of the middle layer. The bus cycle time is in the region of 10ms, suitable adequate control response of typical field controlled devices. Typical transmission speeds between 9.6 kbit/sec and 12 Mbit/sec can be selected.

c. Profibus for Process Automation (PA)

This is the replacement for the traditional 4-20mA control bus. It conforms to the Foundation Fieldbus Physical Standard IEC 1158-2 (as more fully described in the Fieldbus Foundation Section) to allow it to provide loop power off the communications bus.

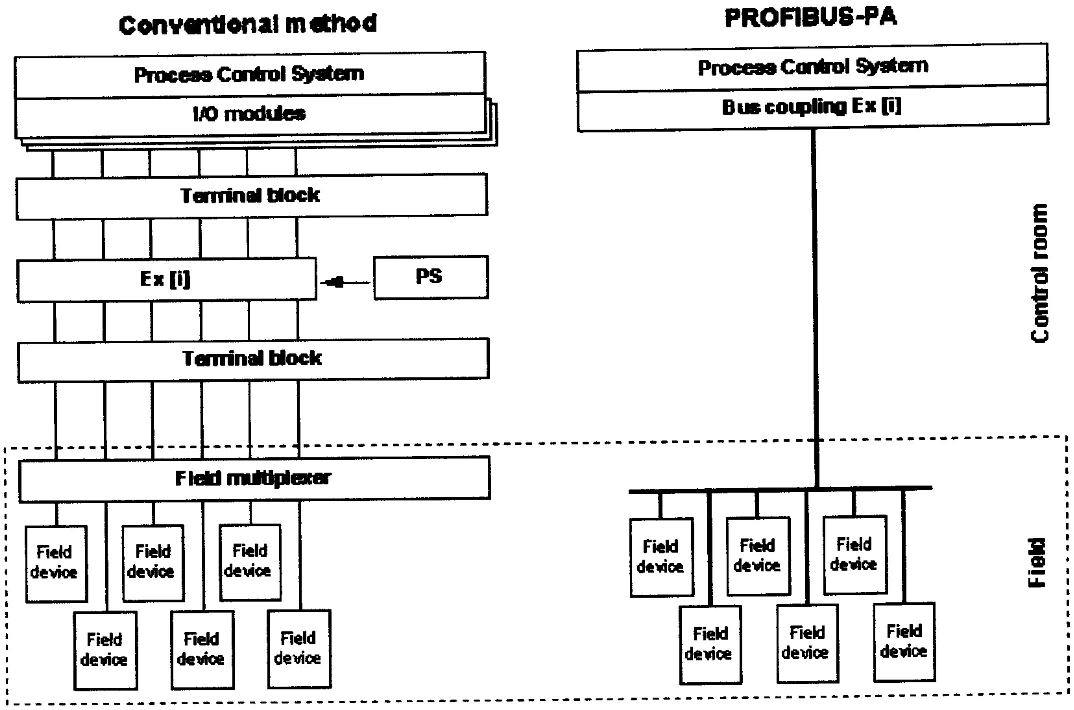

Figure 31: Profibus PA comparison to 4-20mA conventional standard

This self-powered single bus cable approach leads to substantial cable savings, reduced design complexity, and improved future loop reconfiguration flexibility. The Profibus standards do cover device profiles standardising the information available on common nodes such as pressure or level transmitters. This is similar to the Foundation Fieldbus standard. PROFIBUS-PA uses the extended PROFIBUS-DP protocol for data transmission. PROFIBUS-PA devices can be easily integrated in PROFIBUS-DP networks using a segment coupler. Both PA and DP use virtually the same transmission technology and bus access protocol. The bus cycle time is in the region of 10ms, as required for by controlled field devices.

A.3.2 Interoperability Certification

The Profibus user Organization has established a qualified certification system which includes conformance and interoperability testing. Certification is based on a defined standard, EN 45 000. There are also profiles implemented on the standard to achieve plug and play operability. In these parameters of some common devices have been defined in table format so that when a replacement device is fitted the system immediately has access to its set-up parameters. The Interface center is at Fuerth, Germany. Tel +49 911 750 2080, Email: manfred.popp@fthw.siemens.de. Alternatively contact Siemens locally.

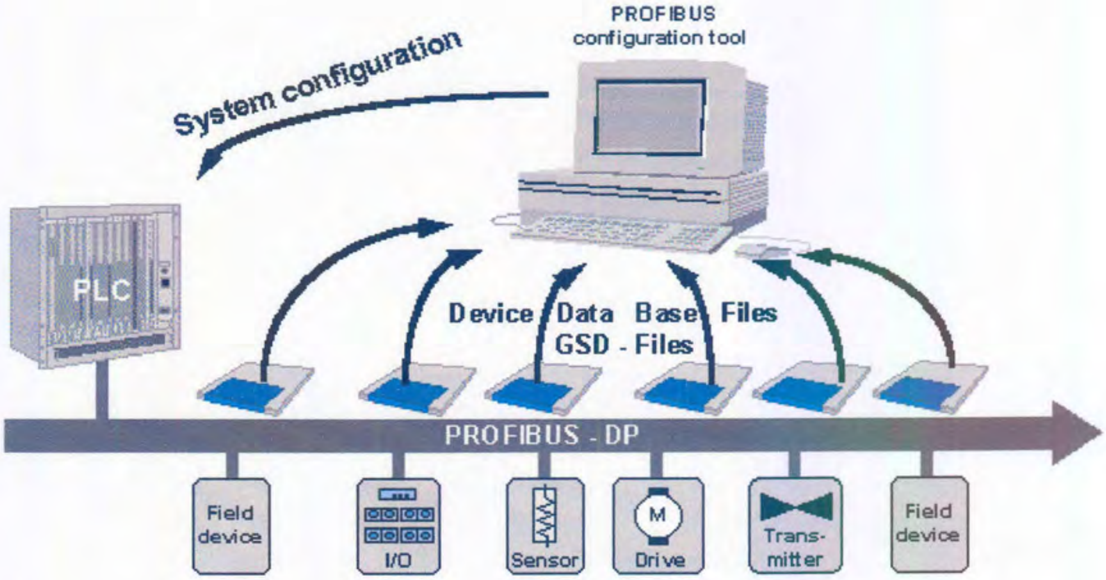

Figure 32: Device Configuration Files

A.3.3 LAN Architecture

The protocol is token ring to allow strict air time control for achievement of communications determinism. Two classes of master exist on the network. Firstly DP Master Class 1 which controls I/O data interchange to its slaves. It is permitted to have multiple DP Master class 1 devices each with their own Slave nodes. Secondly Class 2 Masters which are used for Network Management and Configuration. One can however build a device to act both as class 1 and 2 Masters. Also one can have multi-master systems with the constraint that each slave node can only be written to by one master (class 1) while it can be read by all masters. Multi-master mode does however slow down the bus cycle time. Data transmission takes place between the masters and the DP slaves in three phases every bus cycle:

- Parameterisation
- Configuration and
- Data transfer

A.3.4 Physical Layer (OSI model)

FMS and DP are based on RS485 and PA is based on IEC 1158-2. Fibre optics is an option available with FMS and DP. The topology in both cases is linear bus with active bus termination on both ends,

stub lines only permitted for baud rates of less than 1.5 Mbit/sec. The following diagram is indicative of the layering conformity for Profibus DP, FMS and PA:

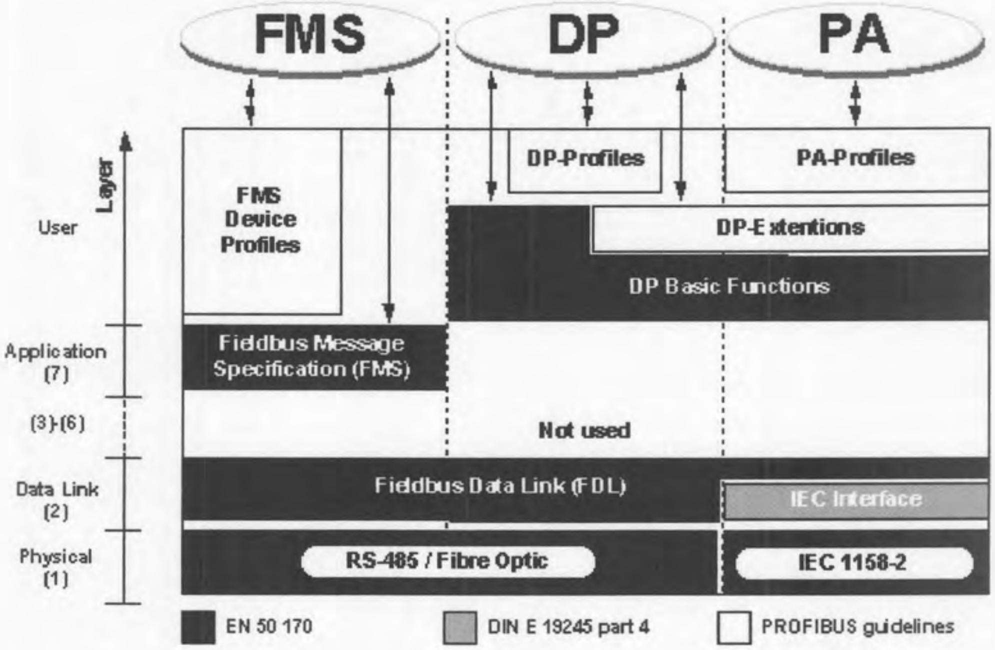

Figure 33: Profibus and the OSI model

A.3.5 Transmission Specifications Summary

	FMS	DP	PA
Data transmission	Speeds between 9.6 kbit/sec and 12 Mbit/sec can be selected		31.25 Kbit/sec; Digital, bit-synchronous, Manchester coding
Data security	Preamble, error-proof start and end delimiter		
Cable	Shielded, twisted pair cable. Shielding may be omitted depending on the environmental conditions (EMC)		Two wire twisted pair cable (shielded/unshielded)
Max Cable run	Typically 1200m at 9.6Kbit/s and 100m at 12Mbit/s		Depends heavily on Powers supply arrangements, typically from 110 to 1900m.
Number of stations	32 stations in each segment without repeaters, up to 127 stations with repeaters.		Up to 32 stations per line segment, maximum total of 126. Can be expanded with up to 4 repeaters
Remote powering	N/A		Optional, via data lines
Topology	Linear bus with active bus termination on both ends, stub lines only permitted for baud rates of less than 1.5 Mbit/sec		Line and tree topologies, or a combination
Explosion Protection type			Intrinsically safe and non-intrinsically safe operation possible

A.3.6 Bus Access Protocol

The protocol is deterministic by means of controlled token passing. The following diagram illustrates the token control from master to master, each one interrogating its slave devices.

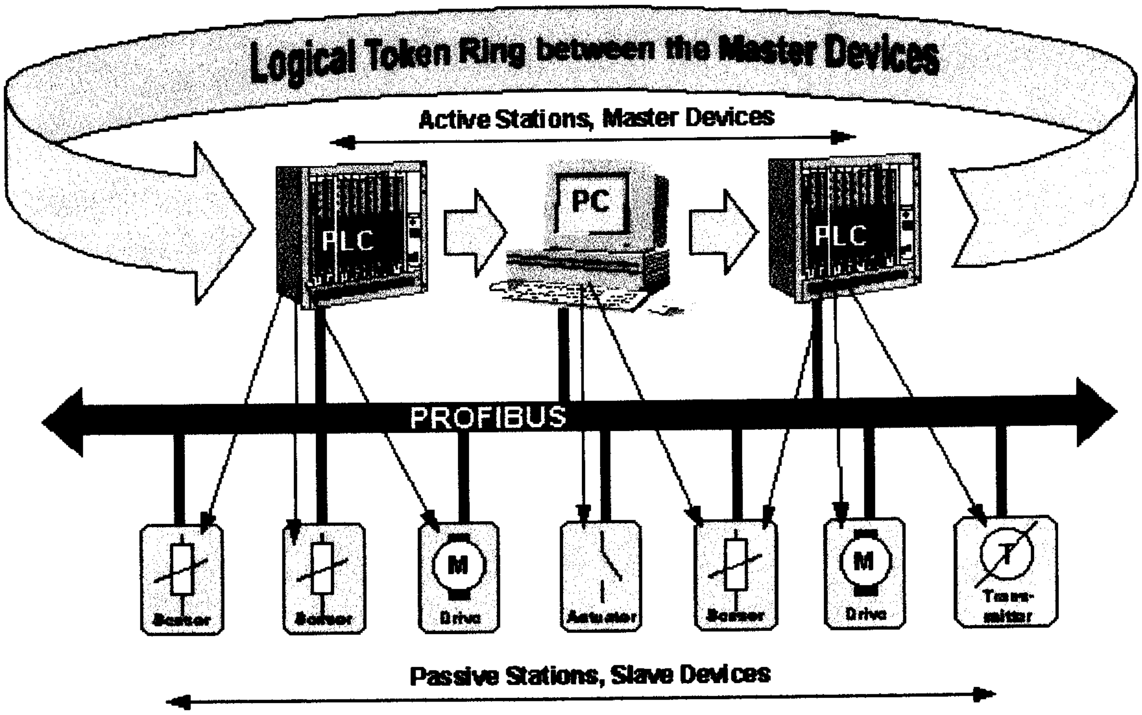

Figure 34: Token Ring Passing in a Multi-Master Environment

A. 4. FIELDBUS FOUNDATION TECHNICAL DETAIL

Foundation Fieldbus is an emerging standard intended primarily for the process control industry. There are two options emerging namely, H1 which is a 31.5Kbps bus implemented on a bus powered, current loop basis, and H2 which is the higher speed option most likely to be implemented on high speed Ethernet. The feature most likely to differentiate Fieldbus Foundation from the market competition is its ability to accept control software functions directly on the field instruments, leading to a greater degree of distributed control.

The diagrams used here are mainly taken from the public website of Fischer Rosemount (reference [18]).

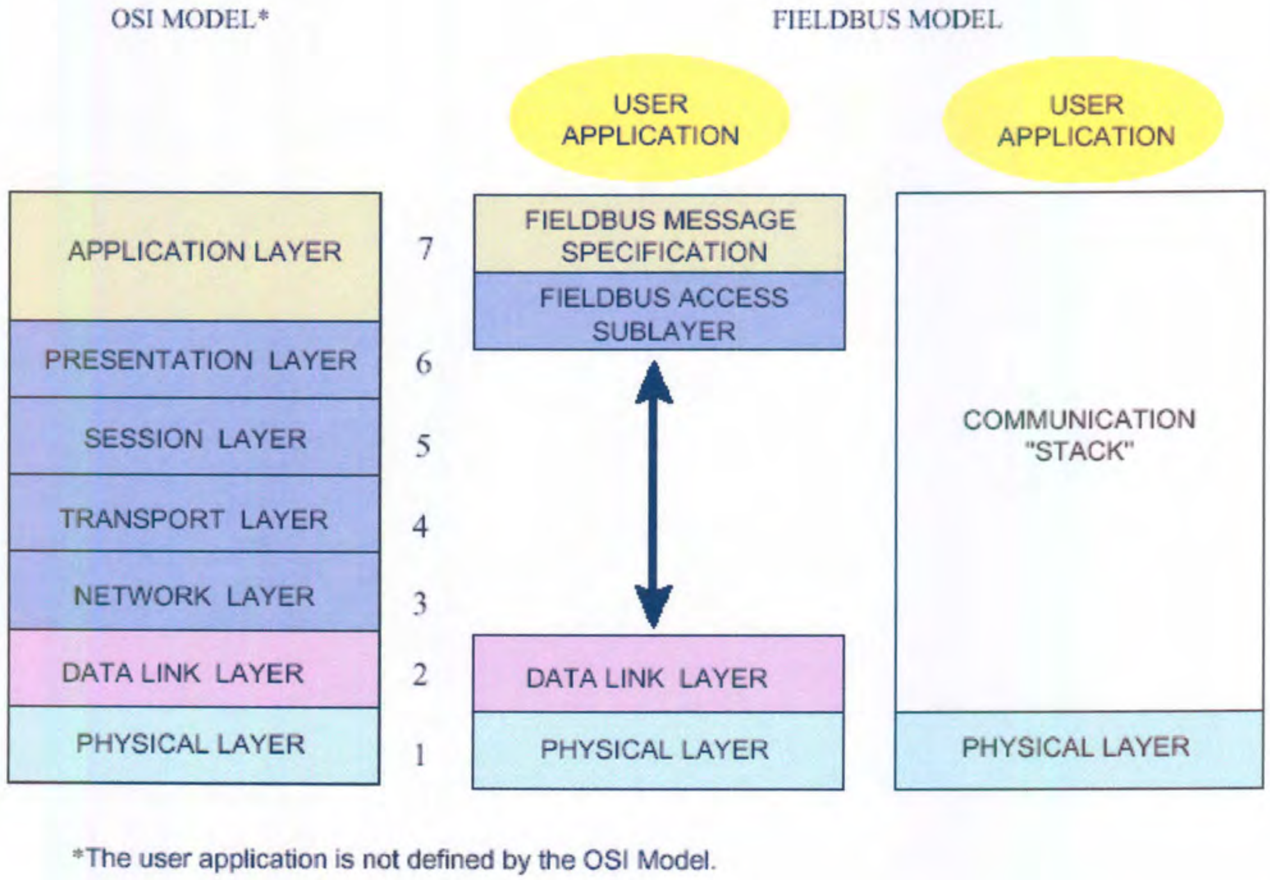

Figure 35: OSI Correlation of Fieldbus Foundation

A.4.1 Correlation with the Seven Layer OSI model

The standard is implemented on three of the OSI layers as shown in Figure 35. This is normal for a fieldbus as it does not require the higher layer routing type services due to the simplified switching requirements of the traffic. The IEC 1158 standard defines the physical layer for the H1 technology, the same standard that Profibus PA has been implemented on. Standards for compatibility of the data link layer are still being finalised, and the latest developments of the standardisation progress is that the Fieldbus Foundation has decided to allow implementation of this on eight different protocol options as discussed later in this section.

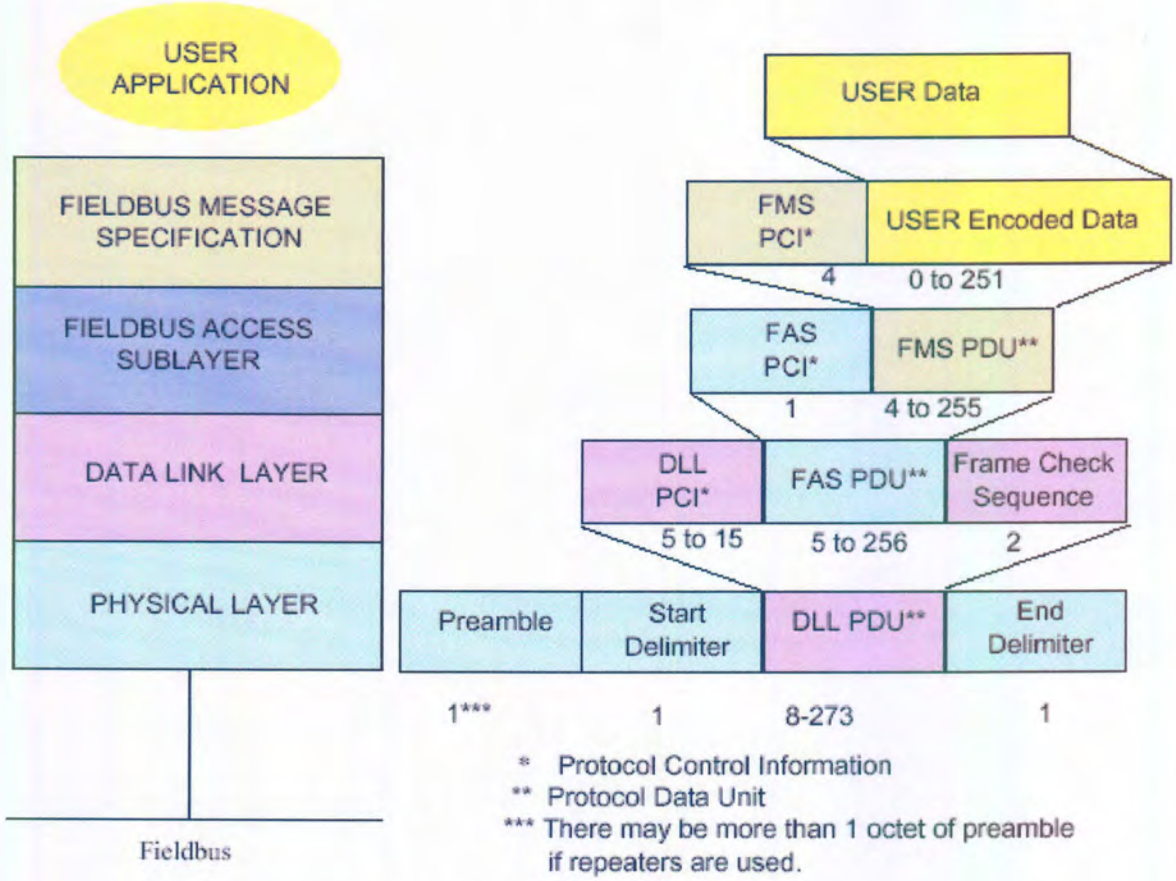

Figure 36: Fieldbus Standard Octet Use

A.4.2 Frame Usage and Encoding

The layers have their control information appended to the frame as shown in Figure 36. The data payload is 251 bytes as opposed to the 274 byte total frame.

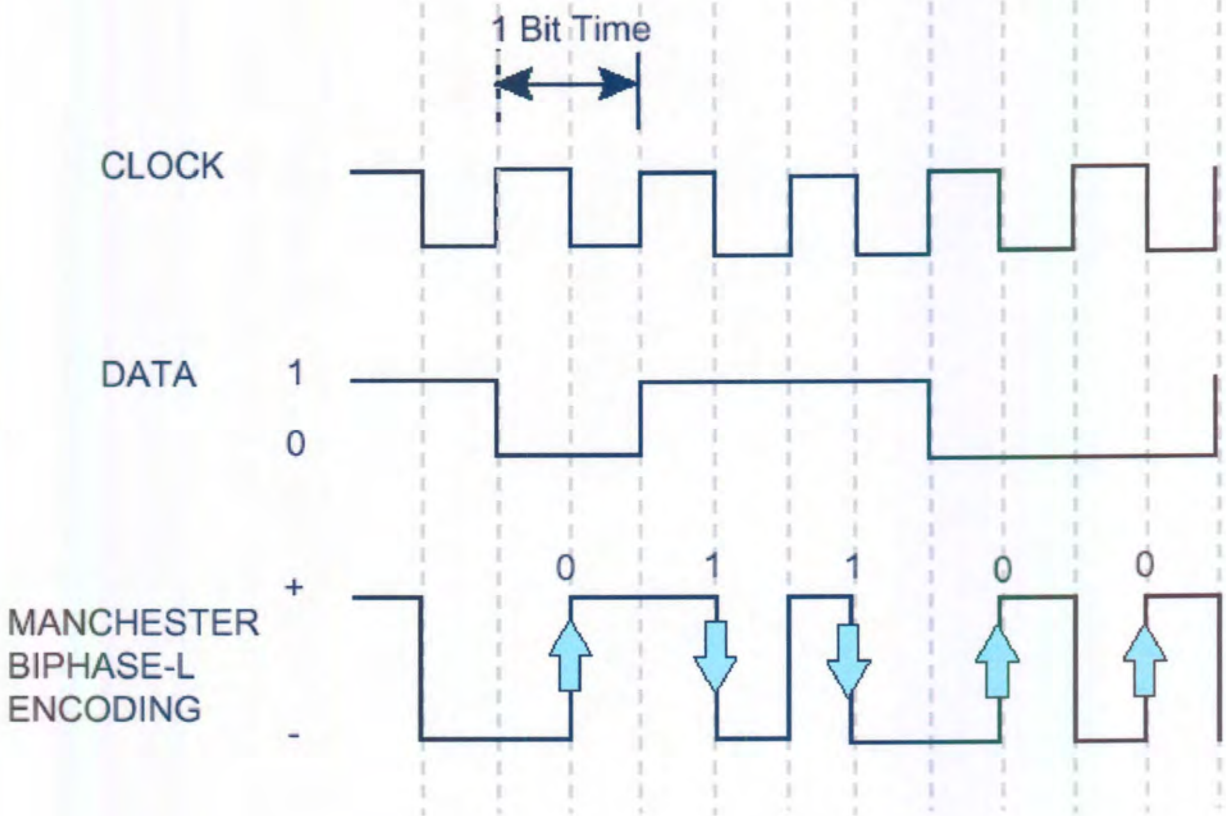

Figure 37: Manchester Encoding

The standard has two versions: H1 the 31.5 Kbps version, and the high speed Ethernet option H2 presently being developed.

H1 transmission is implemented using Manchester encoding as illustrated in Figure 37. With this scheme the signal is encoded as a high-low transition for a one and a Low for a Zero. The receiver looks for the transitions to interpret the data.

H1 transmission is done via current change control as shown in Figure 38.

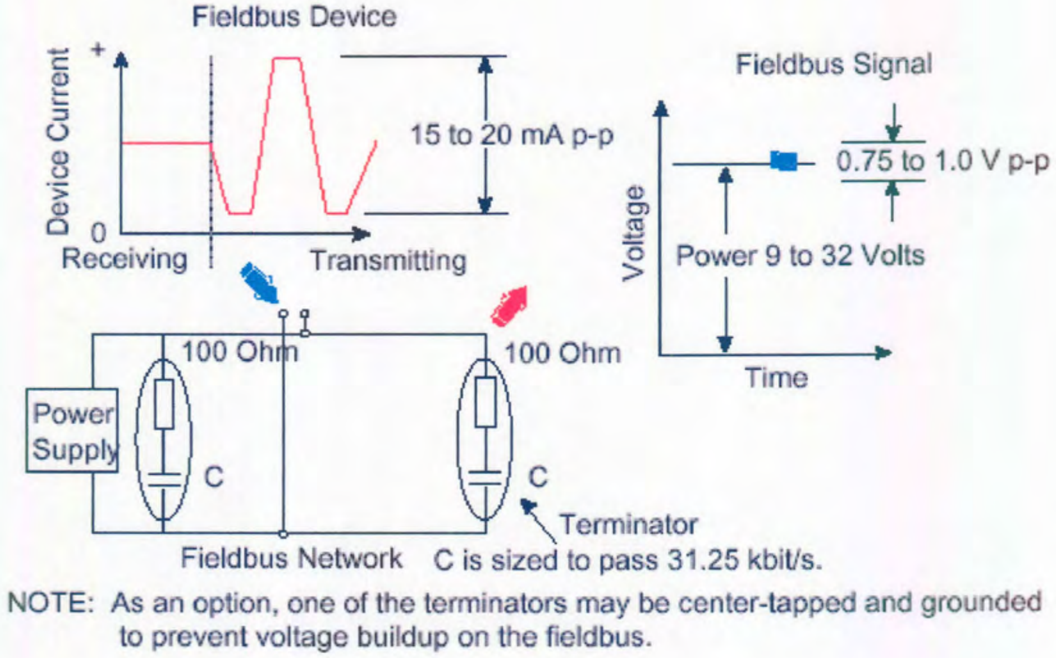

Figure 38: H1 Fieldbus Signalling

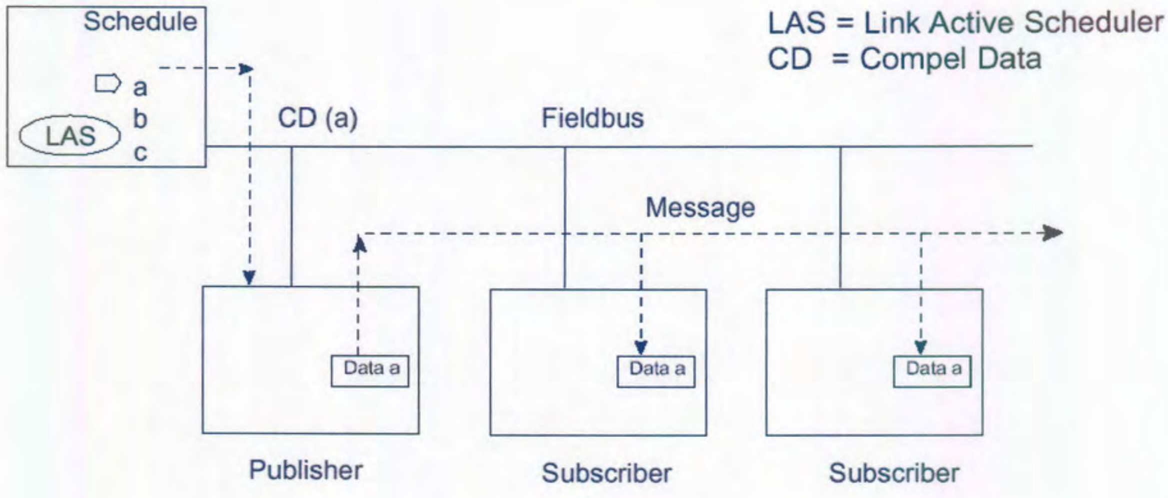

Figure 39: Scheduled Communications Bus Control Illustration

A.4.3 Current Status of the Standardisation Process

The current status on the H1 and H2 standards are as follows:

H1: The Final Draft International Standard (FDIS) for IEC 61158 was passed and it only remains for the IEC Action committee to review voting results and implement as a standard. This draft of the Data Link layer and the Applications layer however contains 8 parallel sections for 8 different protocols which accommodate most of the major protocols (e.g. Profibus, CAN etc..). This choice of eight different protocols is negative with respect to interoperability and has caused some discontentment. The idea the Fieldbus Foundation has is that the market will determine which protocol implementation of the standard is the most effective. As of August 1999 there were 33 registered H1 devices (see reference[26].)

H2: This High Speed Ethernet standard (HSE) is expected to be completed in 2000. The HSE 15 stage testing program is progressing with stage 2 completed, and 3 Prototypes delivered for stage 3 from National Instruments, Smar, and Softing.

The organisation of the Fieldbus Foundation is explained with reference to Figure 40. There are 5 classes of membership having both individual and corporate members, and a total of 130 members. There is an elected Board of Directors that appoints a president who controls an Executive Committee and sub-committees as shown in the chart. The current chairman of the Foundation is John Berra, President of Fisher Rosemount Systems.

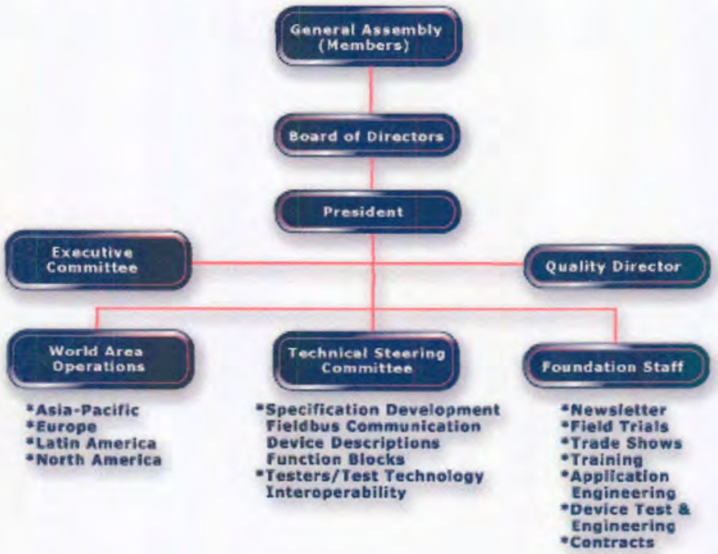

Figure 40: Fieldbus Organisational Chart

A. 5. RADIO FREQUENCY CODE OF PRACTICE GUIDELINE FOR ANGLOGOLD

A.5.1 Definitions

RF: Radio Frequency

COP: Code of Practice

A.5.2 Scope

Radio transmission underground is not subject to legislation regulating RF emission on surface. However it is necessary to manage the use of the RF spectrum underground due to safety and technology management reasons. This COP guideline is intended to cover the important issues in this regard. It is intended that Business Units adopt this as policy to manage their RF usage underground.

A.5.3 Related Standards

IEEE 802.11: For RF LAN Equipment

ETSI 300.325: Spread Spectrum Standards

SABS 1069 (1985): General RF Equipment

SABS 549 (1987): Intrinsically Safe Issues

SABRE: South African Telecommunications Bandwidth Reservation. [27]

A.5.4 Reserved Frequencies

Frequency reservation underground should in all cases be aligned with surface regulations. The latest version of the SABRE project gives detailed guidelines. Incorporating this into the Underground management plan, the following table summarises the reservation required in underground mines.:

Frequency	Application	Comments
100 – 128 kHz	Ecam plus PED system	
300 – 800 kHz	Rescue radios	
150 – 175 MHz	Leaky feeder	Typically for voice transmission and low bandwidth radio modems
404 – 406 MHz	Man Tracking & Asset Tracking	
433 – 440 MHz	Loco Driver to Guard signal	
915 – 950 MHz	Loco remote control/Winch control	*existing cordless phones*
1,2 GHz	Video	Suited to cells of line of sight Communications
2,5 GHz	Spread Spectrum Radio LANS	Suited to cells of line of sight Communications

This table is to be reviewed when the SABRE II project is complete.

A.5.5 Critical Measures

- Safety critical systems must have digital encoding to authenticate point to point transmission. Suppliers remain responsible for the proper safety interlocking involved with the system. A risk assessment should be done by the supplier in liaison with Anglogold regarding the application of safety critical RF systems.
- ·Radio transmission must be limited to within the maximum transmission power as defined by the pending SABS specification regarding electronic detonation devices and RF. In the interim suppliers must ensure that their systems are safe by means of testing and risk assessment and usage guidelines communicated to the mine.

A.5.6 Prerequisite Standards

- ·Leaky feeder systems should be properly engineered and planned before implementation. This involves documenting the future system on the BU communications plan and presenting this to the Anglogold Communications User Group Forum. Arrangements for the presentation of this plan should be made with the Anglogold CIC Manager.

- RF LAN systems should comply fully with SABS 1069, IEEE802.11, and ETSI300.325

A.5.7 Preferred Standards

- Digital radio are preferred systems. A future architecture of a roaming TCP/IP system is envisaged but this currently requires further R&D before implementation.

A.5.8 Implementation and Controls

- Before any system involving RF generation is purchased this must be authorised by the appointed CIC person on the business unit.
- All systems must be recorded on the communications plan showing RF spectrum emission, area of coverage, and number of potential RF nodes (mobile and fixed).
- A record of RF devices must be held by the business unit. This should include the identification number of the device, the RF reception and transmission bandwidth and frequency specification, supplier, model, and responsible person.

A. 6. CONFERENCE ON "EMERGING AND CONVERGING TECHNOLOGIES AND STANDARDS FOR INDUSTRIAL COMMUNICATIONS"

A.6.1 Agenda

8h30 – 9h00: Registration

9h00 – 9h10 : Welcoming and Introduction:

Prof. Ian Craig, University of Pretoria, Electrical and Electronic Engineering Dept – Group Head of the Measurment and Control Department

Web: http://www.ee.up.ac.za/ee/profiles/craig.html

Fieldbus

9h10 to 10h00 Unscrambling the Omelette by Eric Carter

From a user's point of view, there is a confusing selection of communications systems which fall under the 'fieldbus' label. Most implementers of control systems wonder why there is this plethora of available bus types, and why there is not a 'one size fits all' type of bus.

This paper looks at the available bus systems to explain what distinguishes one from another, and why one bus may not in fact be suitable for any application. The paper will cover the ways in which emphasis is placed on the different 'layers' of the modified OSI 7-layer model (reduced to three layers in most industrial buses).

Eric Carter has been involved in control systems for many years, and previously edited Pulse, Sparks Electrical News and Quantum. He is currently an instructor with the well-known training company, Instrument Data Communications. Courses currently presented include Fieldbus, Data Communications, Process Instrumentation, Power Quality, Variable Speed Drives, Power Quality and Intrinsic Safety.

10h00 – 10h30 Profibus: A more detailed Look at Profibus by an International presenter of Profibus International (Siemens Communications Engineer)

This paper covers the more important Technical points of Profibus as a Standard. It simplifies the Organisational Relationships driving the Standard, as well as exploring the Value adding opportunities the Technology presents.

10h30 – 11h00 Fieldbus Foundation: A Solid Alternative by *Alex Jukes of Alpret Control Specialists*

This paper covers the more important Technical points of Profibus as a Standard. It simplifies the Organisational Relationships driving the Standard, as well as exploring the Value adding opportunities the Technology presents.

11h00 to 11h30 Lontalk – an Emerging Communications standard for Rugged Domains by Professor Alwyn Hoffman, Potchefstroom

The Lontalk communications technology and standard has emerged from the building industry and the USA as a significantly beneficial alternative for communications on inferior quality mediums including Power Line borne communications. It also gives good advantage in the free topology it offers network engineers. The paper reviews the main aspects of the technology and illustrates its use in industry.

11h30 to 12h00 Tea and Coffee

The Core Backbone Alternatives

12h00 to 12h30 Fibre Optics as core Backbones by Ben Hayen of Siemens OTN, Belgium.

The paper gives a perspective on emerging standards for fibre optical backbones. It explores SDH as one alternative and relates opportunities where multi-interfaced fibre backbones have secured Value Add in Industry.

12h30 to 13h00 Engineering Aspects behind Fibre Optics by George Hughes, Fibre Optics System Engineer from Fibre Optical Systems.

A review of choices engineers are presented with in installing the fibre backbone. This covers issues such as Multi-mode/ Single Mode, Loose-tube/Tight Buffer, Attenuation, Splicing and many more.

13h00 to 14h00 Lunch

14h00 to 14h30 ATM verse FDDI – The Battle for the Optical highway by Chris Caddick of Anglogold

A paper examining the differences between these two Fibre Optics Standards. The paper highlights the main technical points behind the standards and some important history in the formation of these. It then highlights the strengths and weaknesses of each.

Chris Caddick is a well experienced telecommunications professional having worked in the field for 17 years. Chris currently heads the Vaal River region Telecommunications Systems Support of Anglogold.

Radio Frequency Domain

14h30 to 15h00 Tetra an Emerging Digital Radio Standard by Robin Goodwin (founder member and Secretary of the Southern African TETRA Association)

The paper will review the review the creation, development, current status and evolution of TETRA (TErrestrial Trunked RAdio) as the only open standard, digital technology for Professional Mobile Radio, with particular reference to its use for remote transmission of multi - media information for control and measurement in industrial applications.

Robin is currently Simoco's Regional Director - Sub Saharan Africa, he has spent his entire working life in technical, commercial and strategic roles in the professional mobile communications industry. Previous positions include Managing Director of Simoco's systems business, Strategy Director of Philips Mobile Radio before it was acquired by Simoco, a member of the initial Philips strategy team for digital mobile communications and General Manager of Philips Mobile Radio in South Africa. He has travelled widely in his career including periods of work in Botswana, South Africa, India, Australia, Canada and most countries in Europe.

General

15h00 to 15h30 Technology Management via Domains – An Underground Mining Perspective. By Mark Miller (Control, Instrumentation and Communications – CIC - Manager for Anglogold)

The paper examines the mining process's communications needs in terms of data, voice and video. The total communications infrastructure in a mine has been classified into 4 domains within which Anglogold manages technology for the synergised application of communications systems.

Mark Miller has been active in the CIC field for 10 years managing technology and standards for Anglogold. He is a member of the SACAC executive council. He has travelled to Europe, USA, Canada and South America in various technology searches. Mark has a BSc. Elec. Eng (C&I) from Wits University and is currently completing his M.Eng. in Control Communications with Pretoria University.

15h30 to 16h00: Debate: What does the Future Hold

An open debate on future trends in the field chaired by Francois Laubscher (Executive member of SACAC).

Leading Questions:

- Will Standards converge – Market pressures, Supplier Strategies?
- One Communications Standard for all services or Mutli-domains?

- What is the best practice for users in technology management to maximise Return on Investment?

A.6.2 Summary of Debate

An open debate was held with the questions above as catalysts for discussion. The following summarises some of the more important points made:

- Technology convergence is a joint result of Supplier "Push" and Consumer "Pull". Most communications standards were in the past de-Facto standards resulting from market domination by one or a few suppliers. The establishment of a sufficient population of systems leads to future suppliers conforming to the de-facto standard and bringing their product ranges out on the dominant standard. Today there is a greater role played by the user as more and more users realise the benefits from inter-operability and insist on this when deciding where their money is spent.
- Significant manufacturers are sitting back and waiting the result of a number of competing standards before committing themselves to development of support for a major contender. Where this is most evident is in the support for the new Fieldbus Foundation Standard.
- A single standard for all purposes is not expected to emerge in the medium term future.
- Tetra as a protocol is not supported at frequencies where most underground mining leaky feeder Systems operate.
- General consensus was that TCP/IP was leading the way as a unifying protocol.

A. 7. COST AND BENEFIT ANALYSIS

Table 3: Lost Blast Cause Analysis

Attributing Costs to Total Working Cost	Benefit available if a communications system is implemented in conjuction with other initiatives	Lost Blast causes avoidable with a Comms system and resulting improved management: Qualitiative Assessment (%)
Labour	Flexible Use of Spare Capacity gangs for Cleaning or Support in closely situated panels.	20%
Services	The ability to address Uitlity deficiency quickly. e.g to contact a responsible person to increase air or water pressure.	5%
Material	The ability to order Material immediately and avoid losing a shift waiting for an order.	10%
Equipment	The ability to order equipment immediately and avoid losing a shift waiting for an order.	5%
TOTAL		40%

Table 4: Stope Panel Advance Analysis

Current Stope Advance per month (m)	10	
Blue Sky Potential per month (m)	20	A qualitative assesment of a typical stope advance with no external contraints, i.e. only the capacity of the team holding production back and not avoidable incidents
Assume half of Blue Sky improvement is achievable	15	Assume that with error we can only achieve half full potential. This is a conservative estimate to allow for non-follow through of management effort even when the Comms system is in place.

Advance if avoidable Incidents are eliminated with a Comms system	12

Table 5: Cash Cost Calculation

Current Stoping Labour Cost per sqm mined		137.5	
Current Total Cash Cost per sqm mined		1898	Based on the 1998 Annual Report forcast for SA Operations R/m2
Current Anglogold Sqm mined per year		4200000	Based on the 1998 Annual Report forcast for SA Operations Sqm Mined
Cash Cost before Comms Systems	R	7,971,600,000	

Table 6: Increased Profit Analysis

Strategy to increase Gold Production

Current Gold per year (tonnes)		185.8
Current Gold Price per Tonne Gold	R	58,022,388
Current Revenue	R	10,780,559,701

If we can mine and extra Xm ontop of Ym in every stope = X/Y% increase in production

Conservatively assume that only the stope labour cost comes down but the rest of the cost remains fixed per sqm

Stope Labour/ Total Labour (%)	7%

Hence after Comms Systems:

Stope Labour	R	577,500,000	Remains fixed for improved Gold
Other Cost	R	8,872,920,000	Increase proportionally to Tonnage/Gold Output
New Cash Costs	R	9,450,420,000	

New Revenue	R	12,936,671,642
New Profit	R	3,486,251,642
Old Profit	R	2,808,959,701
Increased Profit per Year	R	677,291,940

Table 7: Approximated System Cost

Typical Costs of a System (PER LEVEL)

	Per Unit	Total Units	Totals		
Base Equipment			R	500,000	
Leaky feeder/m (Installed)	50	15000	R	750,000	
Per stope	60000	10	R	600,000	Approx R30000 per stope; R10/m Leaky feeder; R20,000 per RF LAN RTU
Engineering and installation			R	1,450,000	
Hi Bandwidth Haulage	10000	50	R	500,000	One RF LAN RTU per 100m
TOTAL (per level)			R	3,800,000	

Estimated Yearly Cost of Communications System Maintenance (Running Cost)

Technicians	R	200,000	
Spares	R	190,000	5% of installed capital
TOTAL	R	390,000	

Table 8: Cost for Anglogold

TRANSLATING TO ANGLOGOLD SOUTH AFRICAN OPERATIONS

Levels Per Mine	8
Mines in SA Operations	13

COST OF THE COMMS SYSTEMS

Capital Per Level	R 3,800,000
TOTAL CAPITAL	R 395,200,000
Running Cost/Level	R 390,000
TOTAL RUNNING (Per Year)	R 40,560,000

Table 9: IRR on Comms Systems

IRR:		-39%	113%	146%	156%	159%	160%	161%	161%	161%
	1	2	3	4	5	6	7	8	9	10
	R -395,200,000	R 241,531,940	R 1,273,463,881	R 1,273,463,881	R 1,273,463,881	R 1,273,463,881	R 1,273,463,881	R 1,273,463,881	R 1,273,463,881	R 1,273,663,881
	R -395,200,000	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,931,940
Purchase Cost	R -395,200,000									
Maintenance		R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000
Replacement										
Benefit 1		R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940
Final Value										R 200,000

IRR:		61%	131%	151%	156%	158%	159%	160%	160%	160%
	R -395,200,000	R 636,731,940	R 6,731,940	R 636,731,940	R 486,931,940	R 636,731,940	R 636,731,940	R 636,731,940	R 636,731,940	R 637,031,940
Purchase Cost	R -395,200,000									
Maintenance		R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000	R -40,560,000
Replacement					R -150,000,000					
Benefit 1		R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940	R 677,291,940
Final Value					R 200,000					R 300,000

A. 8. SUMMARY STANDPOINT ON AUTOMATION APPROACH FOR ANGLOGOLD OPERATIONS

A.8.1 Background

Productivity improvement demands, stemming from the need to ensure the extended life of mines and to improve profitability for our operations, have seen the drive for automation and improved decision support systems for operational management. The major Tramming control systems implemented at Kopanang and Great Noligwa were installed in relatively great haste in an effort to take advantage of immediate productivity improvement opportunity, and also as a result of the reduced risk initially offered by the contract negotiated with the Supplier.

Similar projects but with systems of lower functionality have been implemented at Tau Lekau and Tshepong mines (TDS projects).

Recent increased interest in these types of automation systems has caused us to rapidly review communications technologies and automation needs in an effort to more rationally choose future communications infrastructure and specify levels of automation.

In this light an overseas visit was undertaken to review current technology trends in these areas. This involved visits to the UK, Sweden, Canada, and the USA. Mines, Technology Development Centres, and Suppliers were visited. A full report on the visit is available.

Prior to this audits have been carried out on the Kopanang Modular/Centrocen System where some degree of benefits analysis was done and where the functionality of the system was relatively thoroughly examined.

A.8.2 Conclusions Drawn

The activities to date have exposed us to numerous technologies, systems, system developers, system integrators and users. We have obtained a broad overview of what the major users and suppliers of communications and automation systems are implementing and the trend for future developments. We believe we are now in a better position to assist the Anglogold Operations to formulate a vision and best practices for automation and communications infrastructures and standards for the future of Anglogold mining operations.

A.8.3 Automation Drivers

Discussing approaches with mining houses in Sweden and Canada, it is apparent that their mining methodology is a big driver behind their level of automation. They essentially follow methods similar to block cave, and the danger of roof collapse at the mining front is so significant that Tele-remote loading vehicles are necessary. Also the high cost of labour has also made automation alternatives feasible.

Our operations have narrow tabular ore bodies requiring smaller equipment. However our operations have far more people underground and great opportunity exists in maximizing their productivity, increasing face time, managing material ordering, reducing human error/inefficiency. Our solutions call for more logistics control than autonomous equipment operation. In the Tramming scenario with the amount of people we have underground it is extremely difficult to implement driver-less trains but we should consider going for less but bigger autonomous trains supervised by a single person on board, supported by video at the remote end of the train.

A.8.4 Methodology of Introducing Automation

Discussions with users and developers confirmed that peoples "resistance to change" is a major inhibitor to technology implementation.

Major reasons for people's resistance to technology are sighted as:

- The lack of a champion
- The fear of the unknown.
- To a lesser extent the "nothing in it for me" attitude.
- The "not invented here" syndrome.

To ensure smooth technology acceptance and transfer the following points need to be taken care of:

- Clearly identify the technology champion, his/her role, responsibilities and commitment to the technology. Above all ensure that he/she is in the position for the duration and for some time after implementation.
- Keep all the users involved with development through to implementation. This will enable one to evaluate the training requirements, get user buy into the technology, through their involvement and contribution to the technology the not invented here and fear of the technology is eliminated. It will also identify to the user "what's in it for them."

- The single biggest contributor to the fear of technology is trying to do too much at once. By phase technology in small incremental steps one ensures:
- All users are familiar with and train on each phase of the implementation program.
- Each phase is fully functional and debugged before the next phase begins
- The cost benefit of each phase is properly measured and evaluated before the next phase begins. This will facilitate the optimisation of systems.

The following phases are definable:

Level	Communications Infrastructure	Control
1.	Voice over leaky feeder	None, drivers control themselves, requests from those in need of transport directly to the drivers or alternatively from a designated person in the operations
2	Voice, with a monitoring system giving end of shift reports on traffic activities for reactive action	Reactive/Disciplinary/Corrective actions at end of shift
3	Voice, with real time monitoring of traffic over hardwire or radio network or combination	Dispatcher takes decisions on which vehicles must go where. Instructions relayed by voice. Voice recorder if necessary
4	Same as 3	Computer expert system does dispatching. Dispatcher monitors for exceptions.
5	Same as in 3 . Higher bandwidth hardwire Communications backbone to stationary video cameras at loading points. High bandwidth Radio network in cells of automation requirements	Same as in 4 plus driverless trains. Zones of restricted access required while autonomous operations in progress. Obstacle detection technology might develop as an alternative but it is not there yet. Tele-remote operations for loading. Expand to autonomous operation of mining equipment, most likely drilling, with human intervention for charging and blasting

One needs to ask what the optimum level of automation is for our mining scenarios. A single rail or even dual rail system does not require high intelligence software to control. One can argue that the complexity of control is not too great for a central dispatcher with visuals of where traffic is and a good indication of box status. For this reason it is recommended to implement **Level 3** in shafts with Tramming infrastructure pressure, but to do this with a vision of extending to level 4 when we have consolidated on Level 3. Conquering the phase 3 level also allows us to work through the management and control issues of the system before handing this over to an expert system, where we trust the black box approach so much that we do not notice the shortcomings of the automatic system.

A.8.5 Communications Backbones

Leaky feeder has advantages in the way it reduces the complexity of engineering the radio wave propagation requirements underground. A disadvantage however is that delay sensitive real time data in analogue form, such as video, is deteriorated due to multi reception paths. Alternatives exist to convert the video signal to digital and overcome this. The approach some mines have taken is to go for fixed antennae also gaining bandwidth. Considering the advantages of leaky feeder we believe this continues to be the solution for our operations for voice purposes. To be supplemented by cells of high bandwidth point antennas (e.g. the Elequip "Stope Antenna"), and high bandwidth cells as appropriate where demands call for it (typically future type autonomous development loading etc…)

Current projects hence should continue to roll out leaky feeder, however transmission technology on top of this media should preferably be digital transmission. The Tetra standard will now be investigated further as an option together with the Elequip Baseband developments. It now becomes a matter of striving for planned communications backbones for all our shafts, each case with its specific requirements derived from its envisioned automation and monitoring visions.

Fibre as a shaft backbone standard seems already entrenched in our major shafts. The multi-interface standard of Siemens OTN seems most appropriate to interface to our current systems.

Major PLC networks still support their own process field bus standards however it is not too far off where we believe a truly open standard will emerge. Foundation Fieldbus seems likely that it will be that standard. Presently the most practical method of implementing a process field bus is the Profibus PA technology. At least it is on the same physical standard as Foundation Fieldbus.

A typical communications backbone as envisioned is given below and consists of the following: Siemens OTN Fibre as a Shaft Back Bone, Fibre(preferred)/Copper interface to the shaft specific PLCs. An inter-PLC bus (Ethernet preferred), a process control fieldbus of preferably Fieldbus Foundation (when the IEC standard is approved) alternatively Profibus PA . Interfaced to leaky feeder for tunnel type Communications application and cells of stope antenna. For future type high video demand applications then cells of high video bandwidth interfaced to OTN and/or leaky feeder. Echelon for medium or inferior quality such as power lines and fire detection cable.

A generic communications backbone obviously needs application to each shafts specific needs. At times it might make sense to hook on a device, or set of devices, onto an alternative leg of the backbone, e.g. fire detection onto leaky feeder, as opposed to the Echelon network segment. In such a case, if we manage the communications backbone as a utility then this flexibility becomes possible. The key point being that we manage the Communications utility i.e. plan it, document it and train personnel to maintain it.

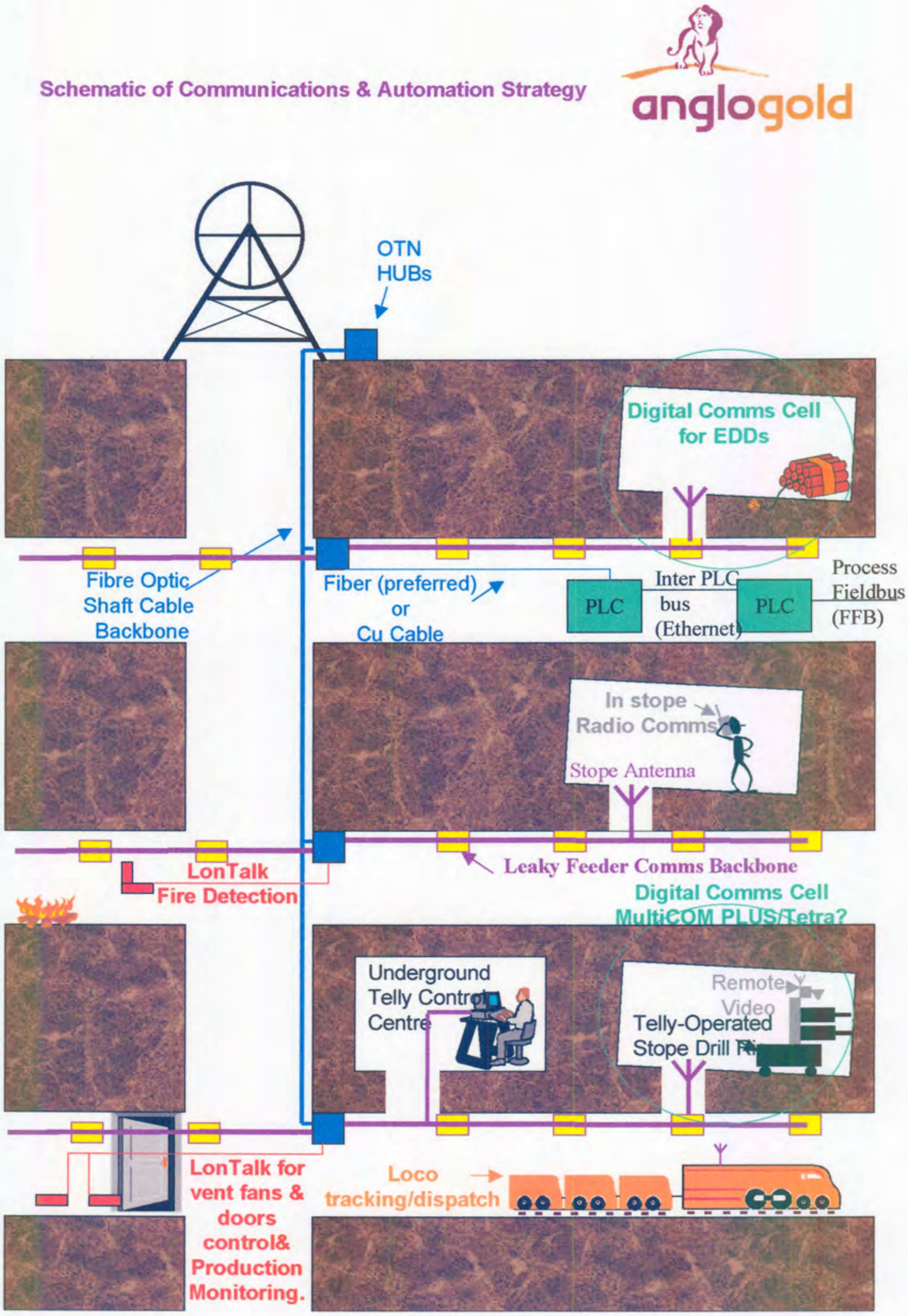

Figure 41: Communications Domains for Automation Standpoint