Installation Testing of 3G Wireless Networks

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Introduction

Continuous demand for broadband services has driven wireless operators to evolve their networks toward third generation (3G) networks. Although IP technology has increasingly penetrated wireless networks, PDH/SDH and ATM are currently the dominating technologies, especially in wireless access networks. Focusing on the wireline portion of 3G networks, this document begins with a short introduction of 3G networks and technologies and follows with detailed descriptions of the test and measurement steps that are necessary for the successful installation of 3G transport networks.

Wireless Networks

Third generation (3G) wireless networks have evolved from 2G/2.5G wireless networks. The very first generation (1G) of mobile communications systems was deployed in the early 1980s. These systems were based on analog cellular technology. Second generation (2G) systems began to appear in the late 1980s. The most dominant 2G technologies were based on Global Mobile System for mobile communication (GSM) and Code Division Multiple Access (CDMA) standards, which were followed by Time Division Multiple Access (TDMA) standards.

The evolution from 2G to 3G traveled different paths. While most GSM-based networks logically evolved toward Universal Mobile Telecom System (UMTS) technology, CDMA-based networks evolved using CDMA 1x EV-DO technology. The focus of this document is the evolution of GSM networks toward UMTS technology (Figure 1).

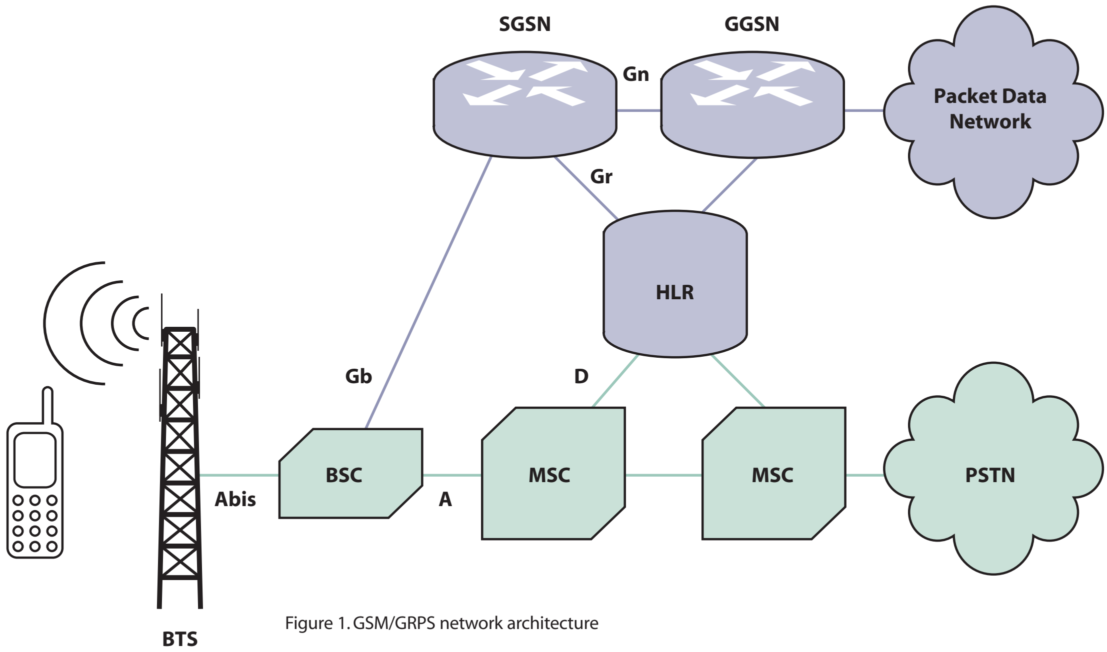

Figure 1. GSM/GRPS network architecture

GSM networks were primarily designed to address the need for mobile voice communication across a wide area. The increasing need for data services made it necessary to enhance wireless networks with an overlay packet network called General Packet Radio Services (GRPS), allowing for high-speed data transfer in an "always on" mode. While most operators have already completed the enhancement of their networks over larger geographic areas with GPRS, some chose to increase their data rates farther by deploying more advanced technologies in their existing radio access networks. These networks offer Enhanced Data rates for Global Evolution and are referred to as EDGE.

Despite the significant performance improvements enabled with GPRS/EDGE technologies, the achievable data rates are still far below those currently experienced by broadband users in telecommunications and cable networks. Advanced applications, such as IPTV and Multimedia Message Services, require data rates of hundreds of kilobits per second and higher. The quest for achieving this level of performance in GSM-based networks made it necessary to adopt a new CDMA-based cellular technology.

With UMTS, a new UMTS Radio Access Network (UTRAN) was added to the previous GSM/GRPS/EDGE network. The key new elements within the UTRAN architecture include the NodeB, located in the cell sites, and the Radio Network Controller (RNC), the counterpart of the Broadband Service Controller (BSC) in 2G/2.5G networks. The orange section in Figure 2 shows the UTRAN portion of the 3G UMTS wireless network architecture.

The initial UTRAN standard established in 1999, also referred to as release 99 (R99), has expanded by several additional releases, known as releases 4, 5, and 6. Release 4 specifies the migration of the circuit-switched voice network to an ATM or IP core network. Other functional areas are also covered by release 4, such as broadcast services and network-assisted location services. Release 5 is mostly concerned with the addition of IP Multimedia Services (IMS), which effectively enable person-to-person multimedia sessions. Release 6 further enhances the capabilities of IMS, increases the uplink and downlink bandwidth, and introduces new Multimedia Broadcast/Multicast Services (MBMS). While wireless networks in most areas are still in pre-3G status, some operators have already enhanced their networks with release 99, 4, 5, or 6 in key geographic areas.

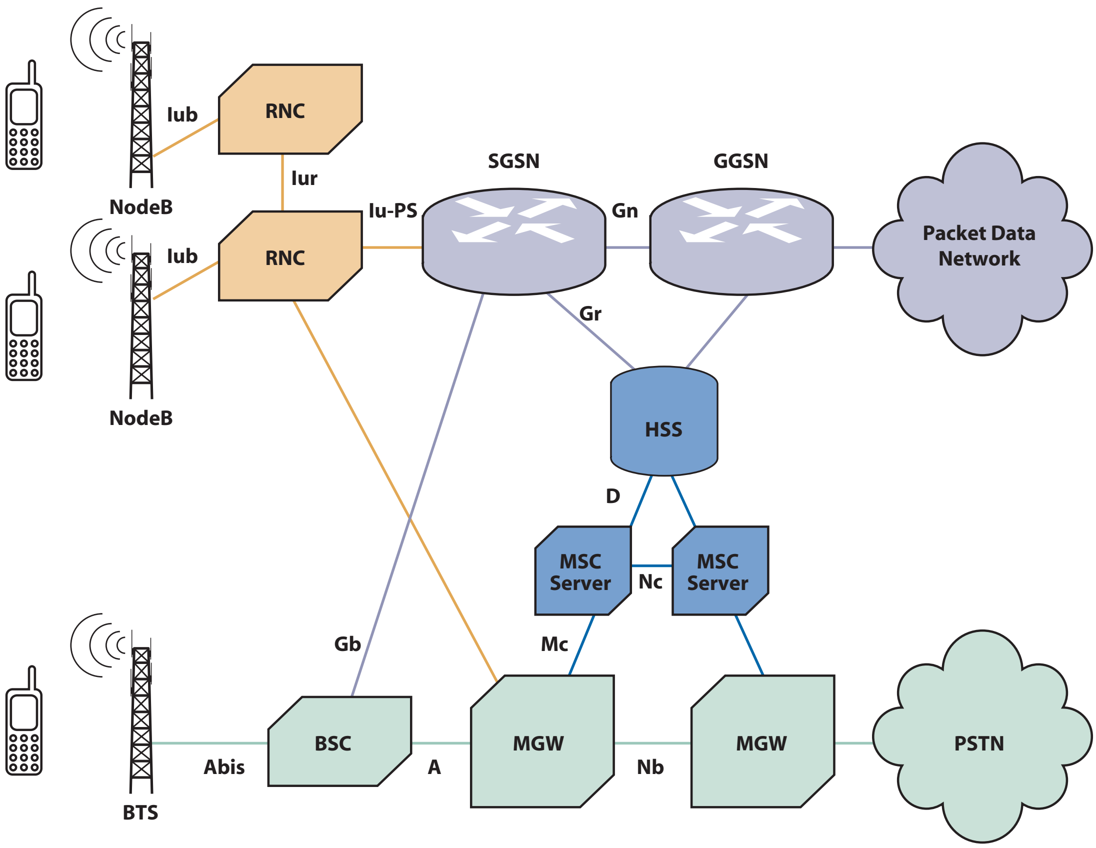

Figure 2. 3G UMTS wireless network architecture

As stated previously, classic Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH) technologies are the most dominant transport technologies in wireless radio access networks. Above the transport layer, ATM is the technology used by 3G UMTS networks to carry both voice and data from cell sites to the switching center. Because ATM is more efficient and reliable than TDMA, it enhances the previous 2G/2.5G mobile service networks, ensuring the required quality of service (QoS). ATM allocates the bandwidth to each user, depending on the requirements of the applications in use. Higher protocols sit above the ATM Adaptation Layer 2 (AAL2) and ATM Adaptation Layer 5 (AAL5). AAL2 and AAL5 carry control and user information along the communication interfaces between the network elements (Figure 3).

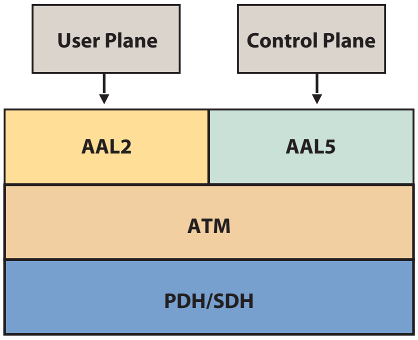

Figure 3. 3G UMTS ATM protocol stack at the NodeB

Installation Testing

Installation of UTRAN networks involves a number of steps that are carried out by different parties, including wireless operators, equipment manufacturers, and operators of backhaul and ATM networks. The following sections provide an overview of the tests and measurements that are necessary for verifying the installation of wireless networks, especially within UTRAN networks. Tests can be performed for installation, monitoring, and troubleshooting at the NodeB, RNC, or even core networks in out-of-service or in-service monitoring modes. Since the demarcation and scope of responsibilities vary significantly among different network operators, the listed testing steps should be regarded as a high-level overview and should be configured according to the scope of responsibilities.

Robust operation of the physical interface is an absolute minimum requirement for reliable network performance. Therefore, any installation of transport links must be followed by basic physical and transport layer tests, including bit error rate tests (BERT), round trip delay (RTD) measurement, and the verification of network operation in the presence of simulated alarms/errors or varying line rate frequencies (offset).

ATM Basics

Asynchronous Transfer Mode (ATM) is a cell-oriented transport mechanism. ATM cells are the smallest standardized information units within the ATM network. All user and signaling information must be represented within this cell format. Each cell encompasses a total of 53 bytes. Five bytes are used for the cell header. The remaining 48 payload bytes are available for user or signaling information. The information in the cell header is mainly used to direct the cell through the ATM network (Figure 4).

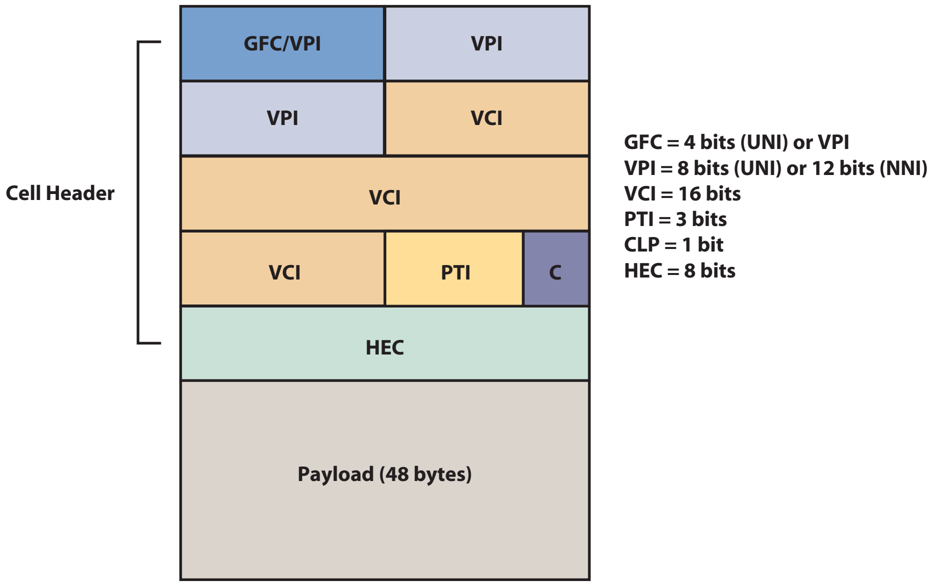

Figure 4. ATM cell format

Some of the more important ATM fields are discussed below:

Virtual Path Identifier (VPI)
The VPI field contains the second part of the addressing instructions and is of higher priority than the VCI field. The VPI combines several virtual channels together. This allows for the rapid change of direction of cells through the network. The network contains equipment, termed ATM cross-connects, that are capable of switching the cell stream in various directions based on the VPI. The VPI and VCI are assigned by the switching centers when the call is established.

Virtual Channel Identifier (VCI)
The VCI field contains part of the addressing instructions. All cells belonging to the same virtual channel have the same VCI. In each case, the VCI indicates a path section between switching centers or between the switching center and the subscriber. All of these different VCIs together mark the path through the network.

Cell Loss Priority (CLP)
The content of the CLP field determines whether a cell can be preferentially deleted in the case of a transmission bottleneck. Cells with CLP-0 have higher priority than cells with CLP-1.

Header Error Control (HEC)
The HEC field is provided to control and, to some extent, correct errors in the header data. The HEC is used to synchronize the receiver to the start of the cell.

The layer model for ATM is composed of four layers based on the principle of the ISO-OSI layer model. To represent ATM accurately, two special ATM layers, the ATM layer and the ATM adaptation layer, were defined. All of the layers are linked together using three communications planes. The ATM layer model is shown in Figure 5.

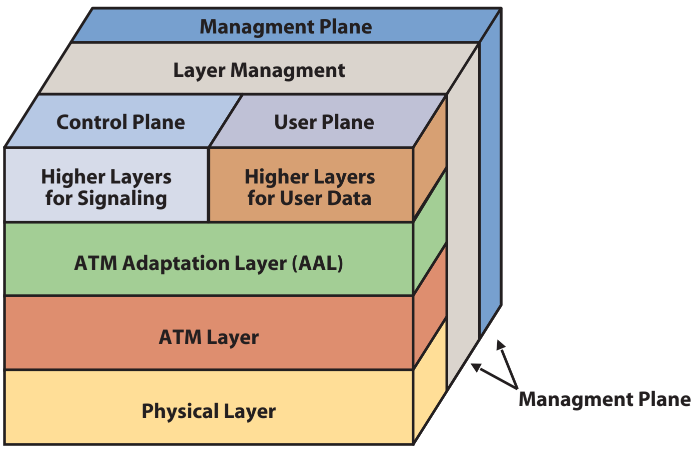

Figure 5. ATM reference model

The functions of the three communications planes are described by the ITU-T as follows:

- The user plane transports the user data for an application. It uses the physical, ATM, and ATM adaptation layers to accomplish this.
- The control plane is responsible for establishing, maintaining, and clearing user connections in the user plane.
- The management plane includes layer management and plane management. Layer management monitors and coordinates the individual layer tasks. Plane management handles the monitoring and coordination of tasks in the network.

The main function of the ATM layer is transporting and switching ATM cells. To accomplish this, the ATM layer adds the cell headers to the data received from the ATM adaptation layer. These headers contain all of the control and addressing information. Cells that are used for special purposes, such as OAM cells, are marked accordingly. The header data is safeguarded against errors using a cyclic redundancy check (CRC) procedure; the result of which is transmitted in the HEC. The ATM layer also evaluates the VPI/VCI information of incoming ATM cells. Evaluation of the HEC is part of the physical layer.

The ATM adaptation layer (AAL), as its name suggests, adapts the data of higher layers to the format of the information field in the ATM cell, according to the services being used. The AAL also reconstructs the original data stream from the information fields and equalizes variations in cell delay. Matching of protocols for the superior layers also takes place in this layer. In order to meet the various requirements that are demanded by data communications, four service classes were created. In turn, these classes are associated with four service types: AAL1, AAL2, AAL3/4, and AAL5. 3G UMTS networks use the AAL2 and AAL5 service types for encapsulation. AAL2 is used for time-critical services that have variable bit rates. AAL5 was created for the special requirements of frame relay and TCP/IP.

ATM Testing

There are two types of ATM tests: out-of-service and in-service.

Out-of-Service Testing

As the name suggests, out-of-service measurements require interruption of live traffic. For this reason, these tests are mainly used during production, installation, and verification, or when major faults occur involving an ATM system that is already in operation. Single ATM channels can still be tested in out-of-service mode even if the entire system is in operation.

In-Service Testing

In-service measurements are mainly used for monitoring traffic. They allow for the determination of the performance of the ATM network. In addition, statistical evaluations can be made to determine network loading. The test equipment is connected to the network without affecting revenue generation by using optical splitters, which tap off a small portion of the optical power from the signal for measurement purposes. Another option is to use test equipment in an in-line or through mode, where the test signal passes through the test instrument. However, the signal itself can be affected when using through mode. A third option is to utilize special test points, which are made available at the nodes by ATM network equipment manufacturers.

By performing ATM tests, the operation of the transport layer is further verified. Instead of testing the network's operation on a physical link-by-link basis, ATM testing allows for an end-to-end verification of ATM, which can be performed from the RNC to the NodeBs, or vice versa. These tests verify the connectivity, throughput, and quality of service of ATM links. Using ATM operation, administration, and maintenance (OAM) features, ATM links are checked for the presence of ATM alarms, and fault localization is performed.

The first step in performing an ATM test involves the identification of the virtual path/virtual channel identifiers (VPIs/VCIs). An RNC can be connected to a large number of NodeBs. Monitoring or troubleshooting a link to a specific NodeB from the RNC requires a test tool that can provide a quick overview of all active links, indicating troubled or congested channels. Congested links are indicated in the cell loss priority (CLP) bit. Monitoring the CLP bit along with the actual cell rate identifies any bottleneck problems as new nodes are added to the network.

Following the identification of the VPIs/VCIs and checking for ATM alarms, an ATM bit error rate test is performed, verifying end-to-end connectivity of the ATM link. This test should be run using the specified bandwidth. Any bit errors, at this stage, are an indication of one of following problems: the mis-configuration of the VPI/VCI mappings in the ATM cross-connects or switches or the incorrect configuration of the VPI/VCI parameters, such as throughput.

The following sections describe several different types of ATM testing, including QoS testing, OAM testing, AAL testing, IP ping testing, and IMA testing.

QoS Testing

While ATM bit error rate measurements provide a good level of confidence regarding the connectivity and throughput of the specific links at the time of installation, the behavior of ATM links in real life - in presence of many different VPIs/VCIs sharing a link - can be quite different. Heavy utilization of ATM links can lead to dropped cells or the delayed transfer of cells while going through ATM switches. Many ATM links, especially in UMTS networks, may have been installed without a significant amount of simultaneous 3G user traffic. As ATM networks are increasingly loaded with 3G traffic, proactive monitoring of ATM QoS is very important in verifying degradation in network quality. The degradation of quality of service is measured in terms of the cell loss ratio (CLR), cell delay variation (CDV), and cell transfer delay (CTD).

Other ATM impairments that may occur include errored cells and misinserted cells. Errored cells contain one or more bit errors and are measured as the cell error ratio (CER). Misinserted cells are cells originally belonging to another virtual channel, which have been mistakenly placed into another virtual channel.

Testing QoS from the end user's perspective involves introducing test traffic (test cells, for example) to one side of the network and measuring the QoS in terms of cell loss, cell misinsertion, cell errors, CDV, and CTD on the other side of the network. Quality of service of the network is typically guaranteed in terms of cell loss and, in certain cases, CDV.

QoS tests usually use O.191 ATM test cells as the payload in the ATM cells. The receiver of the tester synchronizes to the O.191 pattern, decodes it, and compares it to expected values. Other QoS measurements, such as CDV, don't use O.191 test cells. Instead, these measurements are performed on any cell stream by comparing the actual received time with a reference value derived from the cell bit rate.

OAM Testing

Installation testing of 3G ATM networks should include steps to monitor OAM alarm/errors and use loopback capabilities in order to localize the problem area. Besides being used in test and troubleshooting scenarios, OAM tests should be continuously used in monitoring/maintenance mode.

OAM cells allow the ATM network provider to monitor the network for errors, to determine the quality of the connection, and to configure the performance measurement of an ATM network element from a central location. OAM cells take the same path through the network as the user cells. They are located within specific virtual channels and are uniquely identified. The OAM cell format is illustrated in Figure 6.

Cell Header	OAM Type	Function Type	Function - Specific Field	Reserved for Future Applications	Error Dection Code (CRC-10)
5 bytes	4 bytes	4 bytes	45 bytes	6 bytes	10 bytes

Figure 6. OAM cell format

One of the practical applications for OAM cells is for alarm management in ATM networks. If a defect occurs in the physical layer, it is identified in the VP and VC layers (VP/VC-AIS). This causes the OAM cell, with an indicated VP or VC RDI alarm, to be transmitted in the opposite direction. This signals to the transmitting ATM network element that an error has occurred in the transmit path (Figure 7). Five different levels of network management are distinguished. Levels F1 through F3 are assigned to the physical layer, for example SDH or SONET. The information from the physical layer is transmitted using overhead bytes. (For more information, refer to the JDSU SDH Pocket Guide) Level F4 is used for virtual path connections, and Level F5 is assigned for virtual channels. F4 and F5 tests can be performed on an end-to-end (ATM link) basis, or they can be applied to a specific link (segment).

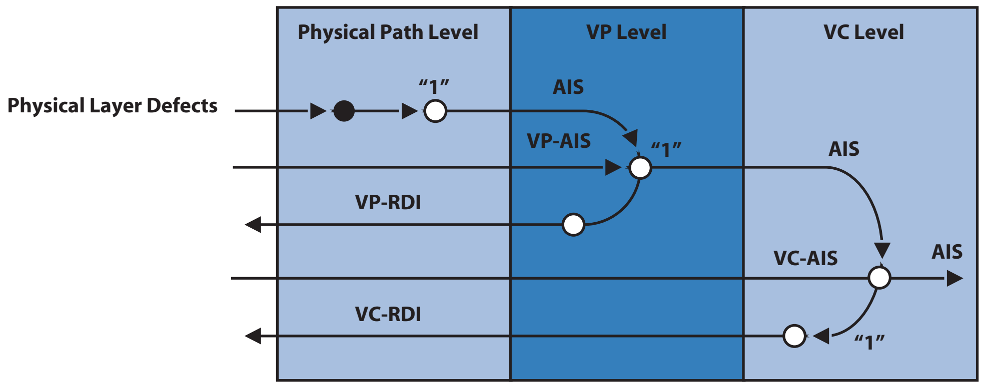

Figure 7. ATM alarm management

Other applications for OAM features include continuity check and loopback capabilities. The continuity check feature provides information to the technician in the event of problems connecting to the ATM network.

An ATM loopback cell can be used to check if a specific destination channel can be reached. The first step typically involves sending an ATM loopback cell with the payload cells set to all ones and requesting a response from the ATM endpoint. A response from the endpoint is proof of the existence of the endpoint and a route to that endpoint from the location of the tester. No response is an indication of an incorrect channel identifier, an absent ATM endpoint, or incorrect mapping. The next step involves setting the OAM loopback cell with all zeroes, causing all of the ATM nodes along the path to respond with their location identifier. This information is helpful in verifying the correct path to the final destination.

AAL Testing

AAL layer tests are useful for fault detection and isolation of specific AAL2 or AAL5 channels. If there are indications of problems along the control plane, an AAL5 level bit error test is performed. In this case, a pseudo random bit sequence (PRBS) or a fixed user-selectable word is encapsulated within the AAL5. The ATM tester checks the received pattern against the expected pattern and provides bit error rate information.

AAL2 connections are more complex and may involve several channels carrying user traffic. An ATM tester with AAL2 generation/analysis capabilities is used to locate possible connection and configuration parameters. The transmitter of the ATM tester is loaded with multiple channels filled with different patterns, and the AAL2 connection is analyzed. On the receiver, the tester provides information regarding possible lost cells, errored cells, or misinserted cells. The type and magnitude of received errors provide an indication of possible causes of the problem, including mis-configured links, congestion/bottleneck problems, or problems involving the network equipment.

IP Ping Testing

IP and AAL5 are used in 3G networks in the control plane. Network equipment, such as NodeBs, are assigned unique IP addresses by responsible parties. Performing an IP ping test verifies IP addressing and connectivity problems. In case of IP ping errors, traceroute functions are useful tools for fault localization. Two types of IP ping tests can be performed: transmit ping and receive ping.

The transmit ping test involves sending IP ping commands to a known remote IP address. When an IP ping test is initiated, the test packets are sent to the target address. If the IP ping commands reach their target IP node, they are returned to the tester, which confirms the receipt and displays round trip delay information for the total amount of time required to travel from the source through the IP network to the final address and back. Otherwise, the tester displays a timeout message. In the case of a timeout message or larger round trip delay values, a traceroute test is recommended. The traceroute test provides information regarding the intermediary nodes to and from the destination address.

In a similar manner, a receive ping test can be performed. The far end station sends IP ping commands to the tester, which is set to ping in receive mode. The tester automatically returns the IP ping commands. This test verifies the correct IP setting of the near end station and the underlying ATM virtual channel connection.

IMA Testing

The Inverse Multiplexing for ATM (IMA) protocol allows for the use of multiple E1 links as a group in order to provide an aggregate bandwidth. The ATM transmission protocol is already being used to carry all of the signaling, voice, and data information for 3G networks. The use of IMA ensures that the bandwidth from each E1 link is proportionally utilized. The IMA protocol involves inverse multiplexing and de-multiplexing of ATM cells in a cyclical fashion among links that are grouped to form a higher bandwidth logical link whose rate is approximately the sum of the individual link rates. This is referred to as an IMA group (Figure 8).

As providers expand their offerings into new data and wavelength services, test responsibilities are expanding beyond traditional SDH and PDH needs into Data and Optical layer technologies. These users now have the responsibility to install and maintain new network elements and service types that were not present in yesterday's legacy networks. The Transport Module addresses these trends by providing the necessary test functionality to support these services in one integrated module.

Weighing less than 7 kg and operating on battery power for two hours at 10 Gb/s rates, the MTS-8000 is conveniently sized and packaged for mobile applications. Advanced applications such as performing five simultaneous Bit Error Rate (BER) tests at once, measuring Round trip delay and verifying automatic protection switch times enable providers to quickly and accurately resolve problems, speed network deployment, and enjoy the convenience of a truly field solution.

For productivity enhancements, the easy to use graphical interface enables users with limited test experience verify performance parameters and ensure that services meet desired quality metrics. In addition, the user interface is based on the industry standard TestPad and MTS product families, allowing existing customers to seamlessly migrate to the MTS-8000 platform. In combination with customizable scripting, saved setups and remote operation this solution enables time efficient deployment and maintenance of revenue generating services. However, in contrast to today's test solutions, the Transport Module doesn't sacrifice scalability or feature depth for convenience.

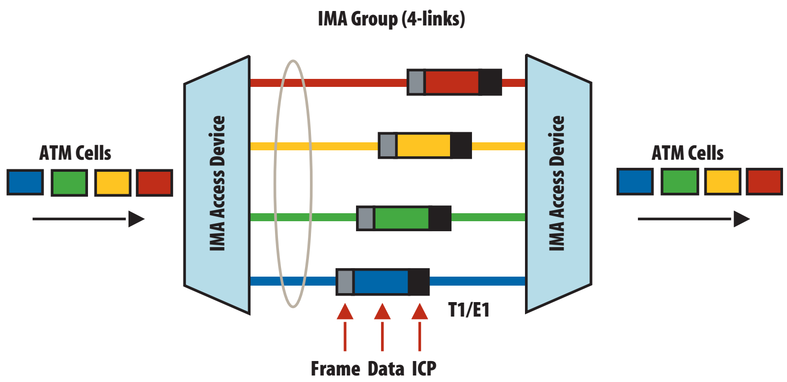

Figure 8. IMA group

IMA groups terminate at each end of the IMA virtual link. In the transmit direction, the ATM cell stream received from the ATM layer is distributed on a cell-by-cell basis across the multiple links within the IMA group. At the far end, the receiving IMA recombines the cells from each link, on a cell-by-cell basis, recreating the original ATM cell stream. The aggregate cell stream is then passed to the ATM layer. The transmit IMA periodically transmits special cells containing information that permits reconstruction of the ATM cell stream at the receiving IMA end after accounting for the link differential delays and smoothing the CDV introduced by the control cells. These cells, termed IMA control protocol (ICP) cells, provide the structure of an IMA frame. The transmitter must align the transmission of IMA frames on all links (Figure 9). This allows the receiver to adjust for differential link delays among the constituent physical links. Based on this required behavior, the receiver can detect the differential delays by measuring the arrival times of the IMA frames on each link.

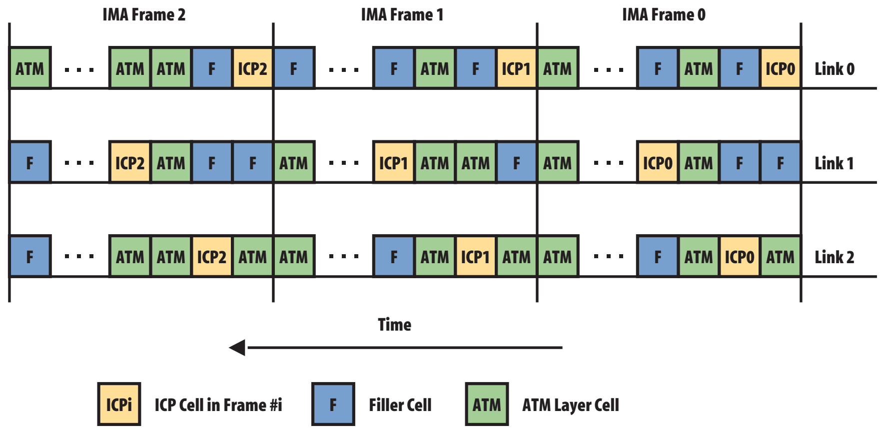

Figure 9. IMA frames and ICP cells

The content of the ICP cell is divided into five classes:

- A: Link-specific information transmitted only over the specific link
- B: Group-specific information transmitted over all links in the group
- C: Link-specific information transmitted over all links in the group
- D: Unused octet
- E: End-to-end channel

The same content of the fields appearing under classes B and C is transmitted over all links within an IMA group. Therefore, monitoring any active link within an IMA group provides information on not only the attached link, but also on the status of the other links and the whole group. Errors on attached links or adjacent links are indicated in the ICP protocol along with the identification of the link. This provides a unique opportunity for an IMA tester to periodically check the status of a group. The tester can provide the status of the whole group and each individual link.

Glossary

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
AIS	Alarm Indication Signal
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
CBR	Constant Bit Rate
CDMA	Code Division Multiple Access
CDV	Cell Delay Variation
CER	Cell Error Ratio
CLP	Cell Loss Priority
CLR	Cell Loss Ratio
CRC	Cyclic Redundancy Check
CS	Convergence Sublayer
CTD	Cell Transfer Delay
EDGE	Enhanced Data Rates for Global Evolution
GFC	Generic Flow Control
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
HEC	Header Error Control
ICP	IMA Control Protocol
IMA	Inverse Multiplexing for ATM
IP	Internet Protocol
LAN	Local Area Network
LOC	Loss of Cell Delineation
MSC	Mobile Switching Center
MTIE	Maximum Time Interval Error
OAM	Operation Administration and Maintenance
PCR	Peak Cell Rate
PDH	Plesiochronous Digital Hierarchy
PRBS	Pseudo Random Bit Sequence
QoS	Quality of Service
RDI	Remote Defect Indication
RTD	Round Trip Delay
RNC	Radio Network Controller
SDH	Synchronous Digital Hierarchy
SGSN	Serving GPRS Support Node
SONET	Synchronous Optical Network
STM	Synchronous Transport Module
TCP	Transmission Control Protocol
TTL	Time To Live
UBR	Unspecified Bit Rate
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
UNI	User Network Interface
UPC	Usage Parameter Control
VBR	Variable Bit Rate
VC	Virtual Channel
VCC	Virtual Container Connection
VCI	Virtual Channel Identifier
VP	Virtual Path
VPI	Virtual Path Identifier
WCDMA	Wideband Code Division Multiple Access

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