# 3G Networking Protocols: The Bridge Between the Air Interface and the UTRAN

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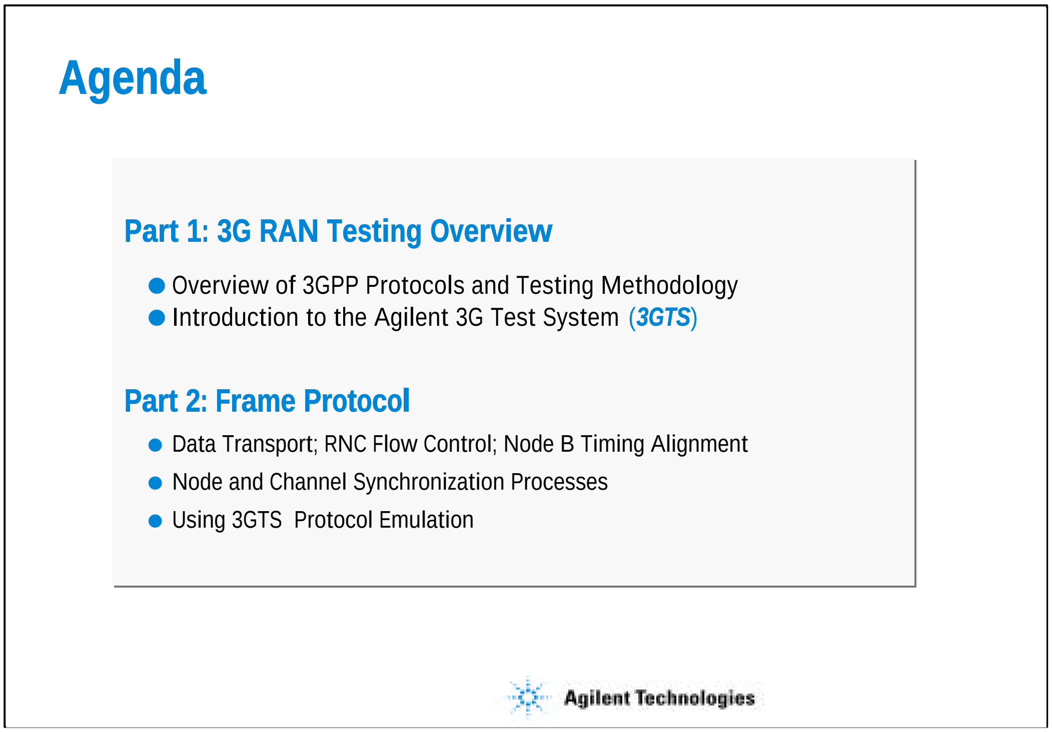
Innovating the HP Way

**Technology and Testing Methodology Overview**
**Using the Agilent 3G Test System (3GTS)**

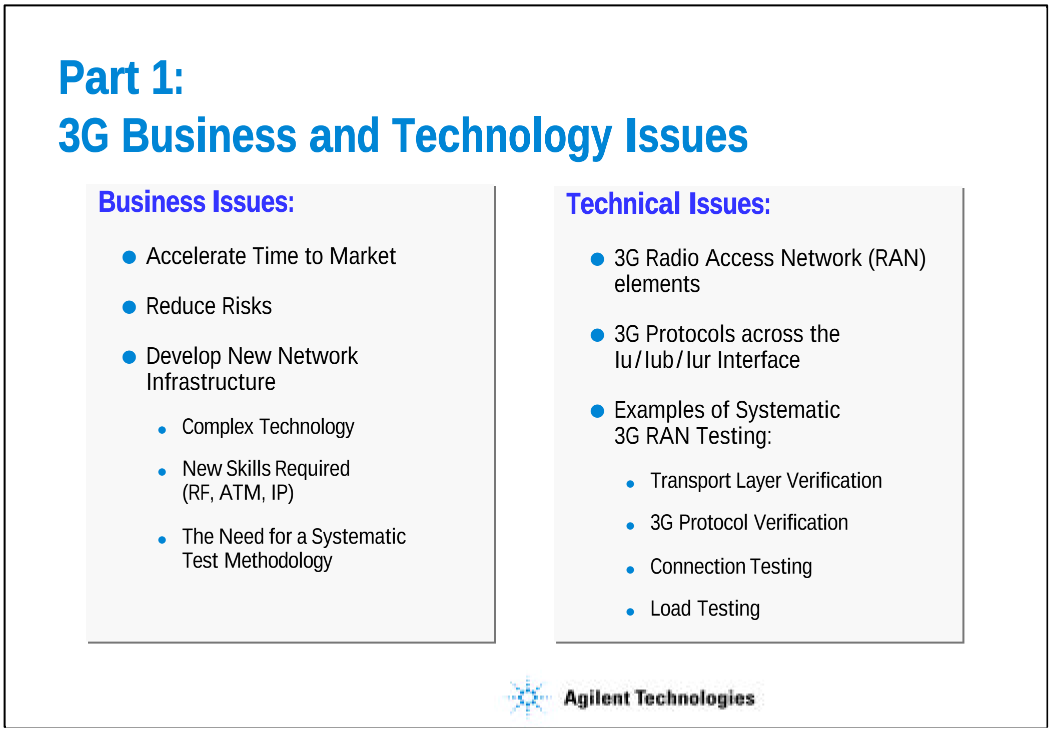
This paper examines interactions between the RF (air) interface and the UMTS Terrestrial Radio Access Network (UTRAN). These concepts are important for people involved in the design and system integration of 3G network elements, such as the Node B (base station), as well as providers of next-generation mobile voice and data services.

The UTRAN provides the connection between the mobile user equipment and the Internet or Public Switched Telephone Network (PSTN) via an ATM-based transport infrastructure. 3G networking protocols are involved in processes such as connection establishment, base station handover, and network timing synchronization. These functions are required to provide high quality, uninterrupted mobile voice and data services, independent of the position and movement of the user equipment or RF fade conditions.




The paper explores the following issues:

- Introduction to UTRAN protocols
  - 3G network overview
  - 3GPP protocols for the Node B (Uu and Iub interfaces)
- Frame Protocol: Functions and Deployment Issues
- Data and Control Channel Structure
  - Frame TTI (Time Transmission Interval)
  - Base station timing synchronization
- 3G Networking Protocol Testing Techniques
  - Introduction to Agilent 3G test system (3GTS)
  - Functional and performance testing
  - Test cases: base station synchronization; diversity handover




**3G Business and Technology Issues**

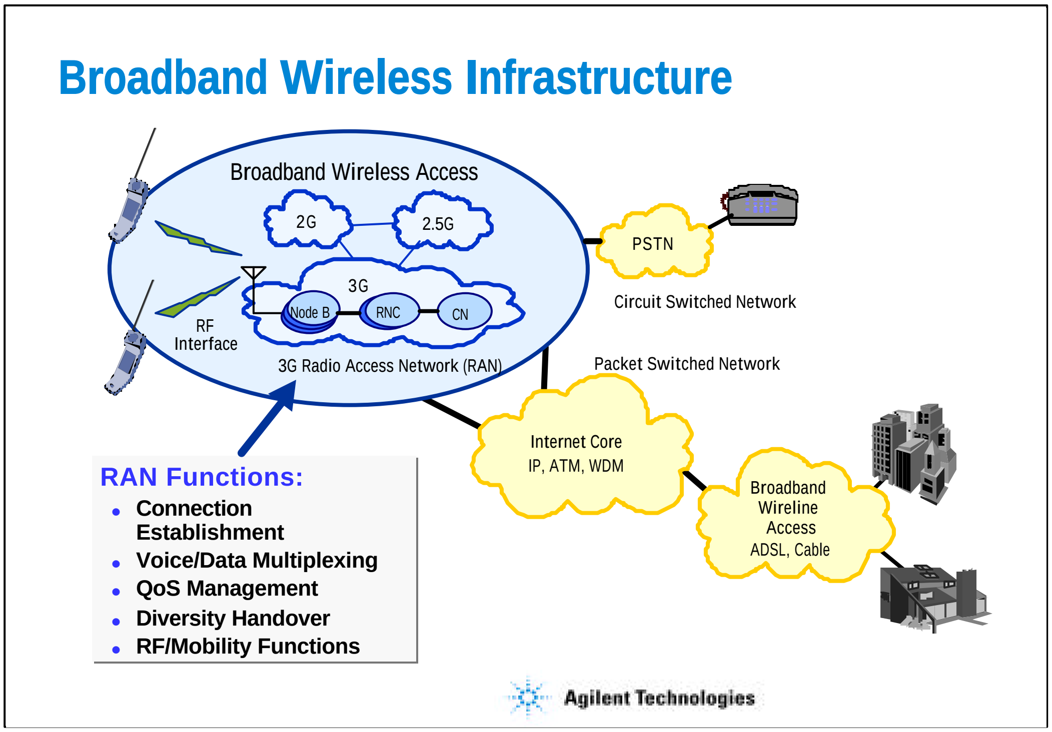
Third Generation cellular wireless technology provides much greater levels of functionality and flexibility than previous generations (for example, 1G analog and 2/2.5G digital GSM/CDMA/GPRS systems). 3G offers improved RF spectral efficiency and higher data bit rates, up to 2 Mbps.

An early benefit of 3G technology will be improved mobile telephone services and significantly increased system capacity. For example, multi-mode phones will enable seamless global roaming capability (ability to use the same handset anywhere in the world). In the longer term, 3G is also expected to become a significant Internet access technology, providing mobile data rates ranging from 144 kbps to 2 Mbps with guaranteed Quality of Service (QoS) levels.

However, the benefits of 3G come at a cost. RF spectrum licenses are extremely expensive and a large number of companies are competing to enter the market. The first few companies to market with new 3G voice and data services are likely to retain a significant competitive advantage in the long term.

At the same time, 3G systems are significantly more complex to design and operate and require multi-protocol support, particularly across the terrestrial Radio Access Network (RAN). Finding enough skilled employees presents an additional challenge, as many people who come from a 2/2.5G background face a steep learning curve to gain the required experience in ATM and IP technologies.

In an environment that includes high levels of investment, competition, and technical complexity, combined with a critical skills shortage, there is a strong need for equipment manufacturers and services to adopt strategies that minimize risks and accelerate time to market. In this paper, we will look at a systematic approach to verifying the functions and performance of the 3G RAN and its network elements.




**3G Network Infrastructure**

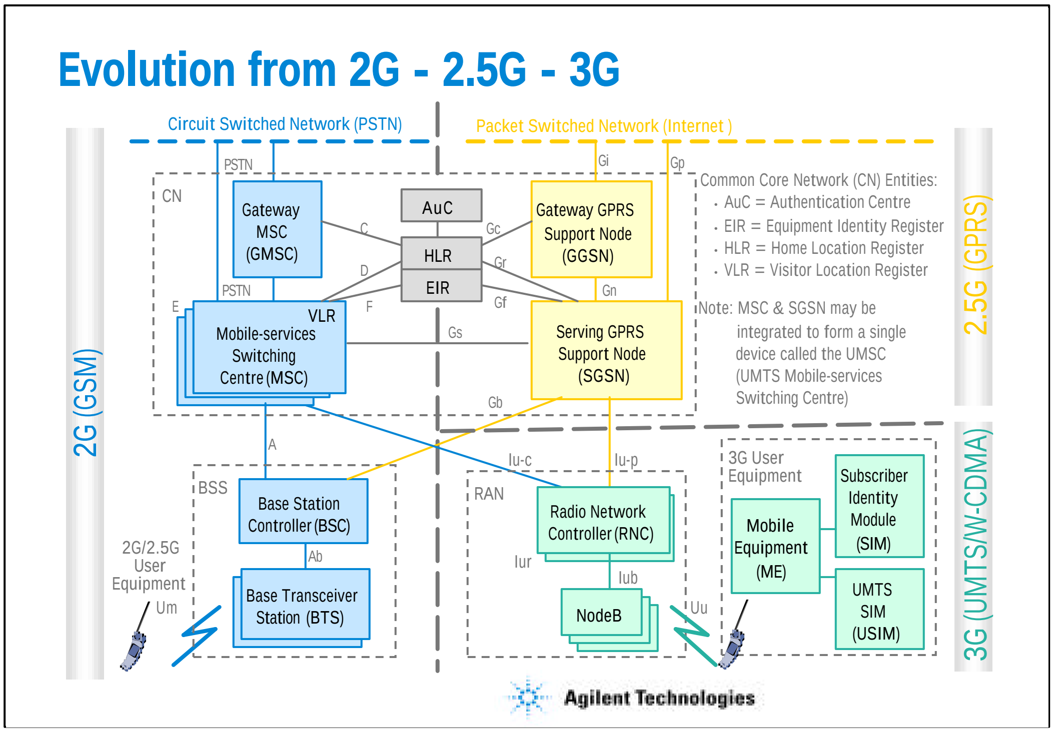
Because of its potential to provide high-speed data services, 3G is likely to emerge as an alternative to existing broadband access technologies such as ADSL and cable. From a user perspective, 3G is purely an RF technology. However, from a service provider viewpoint, there is a significant amount of wireline (also called terrestrial) network infrastructure to install and operate.

The wireline components of the 3G system are referred to collectively as the **Radio Access Network (RAN).** The 3G RAN is designed to handle broadband wireless access and mobility functions, independent of the core network technology. It is responsible for session management and connectivity to the public switched telephone network (PSTN) and Internet. The 3G infrastructure must also inter-work with existing 2G (for example, GSM, CDMA) and 2.5G (for example, GPRS) mobile systems.

3G services operate over an ATM infrastructure that is designed to inter-work with existing circuit-switched and packet-switched public networks. This is achieved by overlaying 3G-specific protocols on an ATM-based transport infrastructure. Functions such as data/voice multiplexing, QoS management, and connection establishment are based on existing ATM capabilities, such as the AAL-2 and AAL-5 adaptation layers, and UNI and NNI signaling protocols.

Additional 3G-specific protocols are required to handle the connection-setup procedure between the RF (wireless) and terrestrial (wireline) parts of the network. These protocols also support mobile-specific features such as diversity handover. This is a complex procedure that requires co-ordination between signal quality measurements on the RF side, and multi-connection establishment through the wireline infrastructure.

In this paper, we will focus on development and deployment challenges of the 3G RAN.



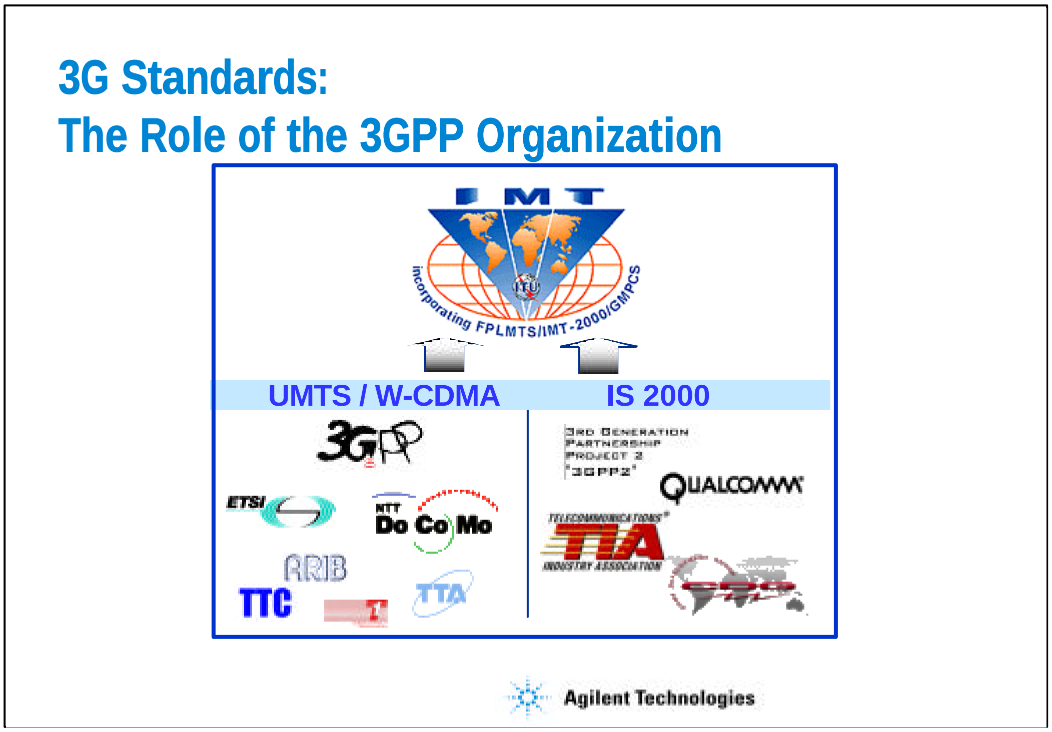

**Evolution from 2G to 2.5G to 3G Wireless**

3G is an evolution, rather than a revolution, in terms of the principles of mobile network architecture. The 2G network provides separation between the RF-specific functions, known as the Base Station Subsystem (BSS), and the Core Network (CN). This makes the CN relatively unaffected by changes in the RF equipment, such as RF band, or encoding techniques. This approach is continued in 2.5G and 3G systems.

The 2G core network provides the connection to the circuit-switched Public Switched Telephone Network (PSTN). The control functions required to achieve this are generally based on SS7 signalling, commonly used in the PSTN. The basic elements of the 2G system include the mobile equipment (handset), base station, mobile-services switching centre (MSC) and gateway into the PSTN (GMSC).

The 2.5G (GPRS) core network adds packet-oriented switching functions that enable relatively low bit-rate packet data connections to the Internet (typical rates typically in the range 9.6 kbps, up to a theoretical maximum of 182.4 kbps). The General Packet Radio Service (GPRS) is a “connectionless” service, meaning that the Internet connection is available continuously. It tends to be seen as a migration step to 3G.

The 3G RAN adds an ATM-based transport infrastructure that enables connection setup capabilities with guaranteed QoS levels. The 3G RAN is designed to inter-work with both circuit-switched and packet-switched core networks. Benefits include more flexible voice services, higher bit rate data services, and higher service quality levels.



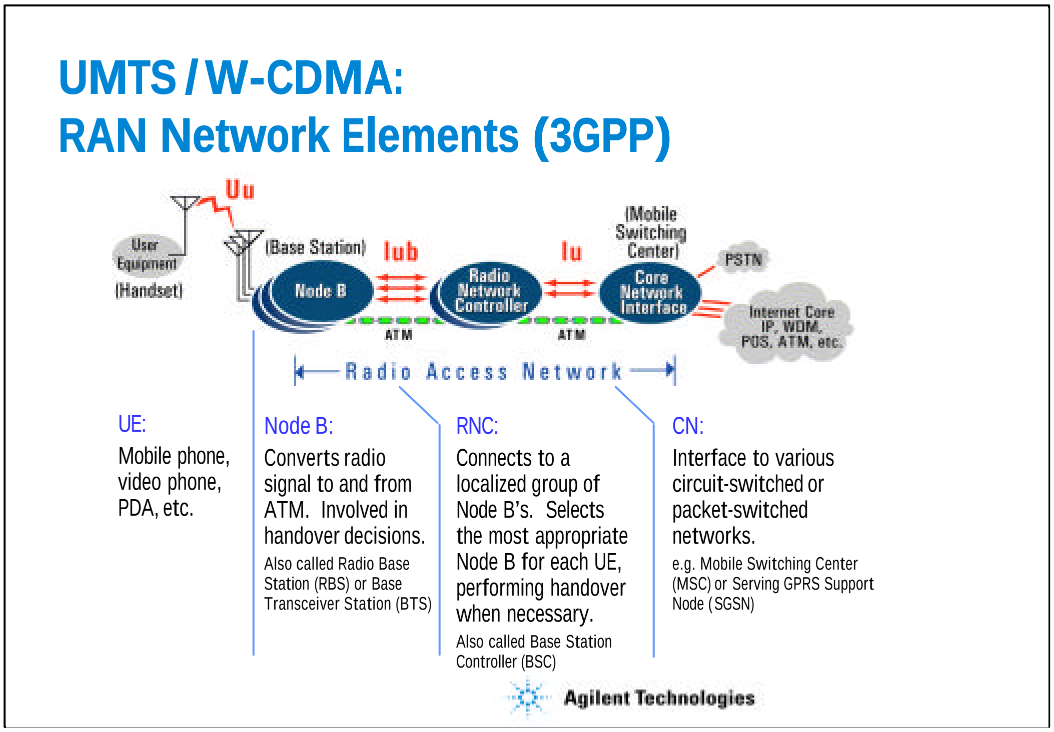

We will review some aspects of UMTS/W-CDMA standards and technology and examine the unique challenges in testing at each of the five stages we have identified.

**3G Standards**

The International Telecommunications Union (ITU) manages the 3G umbrella standard known as **IMT-2000**. This standard endorses five different modes of RF interface, and two major types of terrestrial infrastructure (known as the Radio Access Network, or RAN). The intention is for any of the RF modes to work with any of the RAN types.

The two major types of RAN are **UMTS/ W-CDMA** (predominantly for Europe and Japan) and **IS-2000** (previously cdma2000, predominantly for North America). Scarcity of RF spectrum is a more serious issue in Japan and Europe. This is driving the more rapid development of UMTS W-CDMA, which is expected to account for 70% of 3G cellular subscribers worldwide.

UMTS W-CDMA standards proposals are submitted to the ITU by an organization called **3GPP** (Third Generation Partnership Project). 3GPP co-ordinates submissions from a number of regional standards bodies, such as ARIB, CWTS, ETSI, NTT DoCoMo, T1, TTA, and TTC.




**UMTS/W-CDMA: RAN Network Elements**

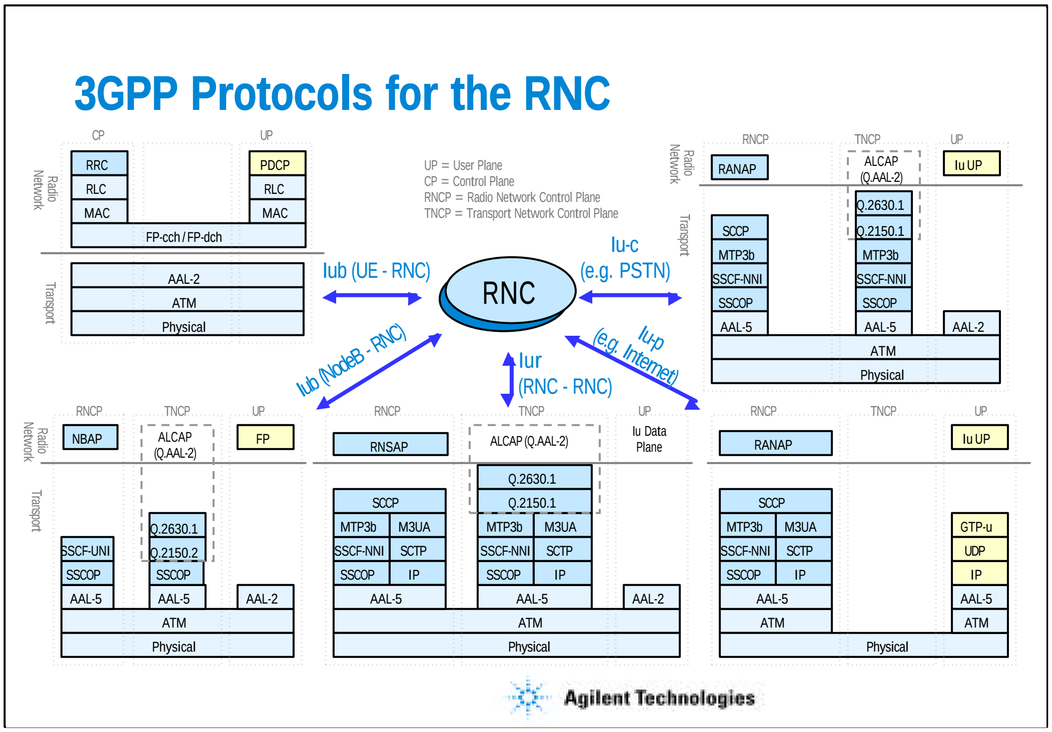
The main components of the UMTS W-CDMA RAN are shown above. The network elements referred to in the 3GPP specifications are User Equipment, Node B, Radio Network Controller, and Core Network Interface.

- **User Equipment (also called Mobile Station or Handset):** includes mobile cellular telephones, handheld Personal Digital Assistants (PDA), and cellular modems connected to PCs.

- **Node B (also called the Base Station Controller or Radio Base Station):** provides the gateway interface between the handset/RF interface, and the Radio Network Controller via the Iub interface. It is involved in handover decisions, which are based on RF signal quality measurements.

- **Radio Network Controller (RNC):** connects to and co-ordinates as many as 150 base stations. It is involved in managing activities such as hand-over of active calls between base stations.

- **Core Network Interface (also called Mobile Switching Center or Mobile Multimedia Switch):** refers to other terrestrial core network infrastructure connected to the RAN through the Iu interface; for example, the Internet and PSTN.



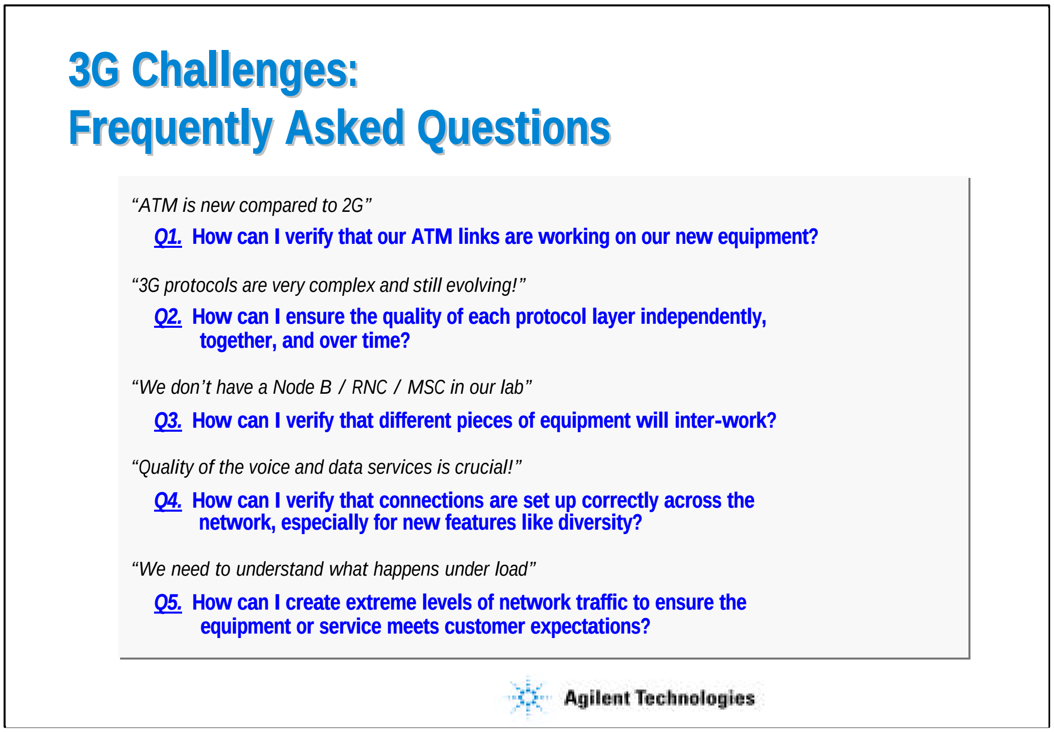

## 3GPP Protocols: Multiple Protocol Stacks to Support

The 3GPP specifications define a set of protocols for communication within and between UMTS W-CDMA radio access network elements.  These protocols manage **control-plane** functions (for example, signalling required for base station handover) and **user-plane functions** (for example, ATM-based multiplexing of voice and data streams from multiple sources).

The 3GPP protocols sit above the ATM adaptation layers (AAL-2 and AAL-5) and operate across the Iub,  Iu, and Iur interfaces.

- The **Iub** is a physical communication interface between the base station (Node B) and the Radio Network Controller (RNC). Connection establishment (discussed later) is a 3-stage process that results in a Radio Access Bearer (RAB) between the RNC and user equipment (UE). The RAB provides voice and data connectivity to the UE.  A different protocol stack is needed for each stage of operation, either Node B - RNC, or UE - RNC.
- The **Iu** is the communication interface between the RNC and the Core Network Interface. It supports different protocol stacks for interfacing with either circuit-switched (for example, PSTN) or packet-switched (for example. Internet) networks.
- The **Iur** is the communication interface between adjacent RNC.

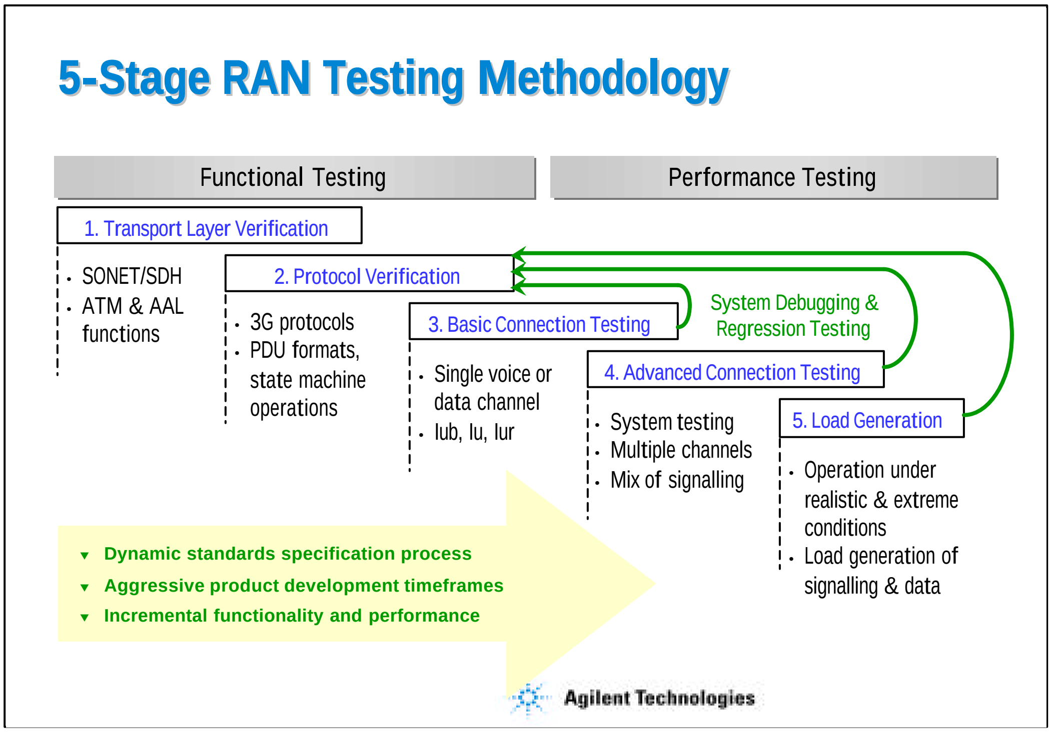
It is beyond the scope of this paper to examine these protocols in detail. However, one message is clear: 3GPP protocols are very complex!




**Development and Deployment Challenges**

Some of the technical challenges for 3G equipment developers and service providers include:

- The migration from traditional 2G network infrastructure to an ATM-based transport infrastructure: ATM connectivity needs to be verified as well as more complex functions, such as QoS and diversity.
- Complex and evolving 3GPP protocols: designers need to verify individual protocols and the way they interact with the rest of the protocol stack. As standards evolve, designs need to be modified and verification tests repeated.
- Time to market issues mean that the various RAN devices (Node B, RNC) are being developed in parallel by different design teams. It is therefore very difficult to completely verify the behavior of the equipment under development.
- Successful connection establishment requires a large number of 3GPP and ATM signalling protocols to operate and interact correctly. Due to the higher performance and reliability requirements for 3G, compared to 2G, advanced features such as diversity handover and multi-diversity also need to be designed and verified.
- Equipment and network performance are important issues. It is not sufficient to know that your 3G components and overall system function correctly. Even if the system works flawlessly in a functional sense, it will not be useful commercially if it can only support a small number of users. 3G network elements and the entire 3G RAN need to handle a large number of voice and data services reliably under normal and high-load conditions. Performance benchmarking of a piece of equipment or trial network is generally carried out under extreme load conditions.




**Systematic Test Methodology: RAN Testing Phases**

Due to the complexity of UMTS W-CDMA systems, large hardware, software, integration, and QA teams are required to develop them. Development of 3G systems can be broken into the following major stages:

- Individual development of hardware, Field Programmable Gate Array (FPGA), and software modules
- Integration of hardware and software modules to form a component
- Debugging and verification of individual components
- Integration and verification of 3G systems made from these components
- Performance testing of individual components and the system as a whole
- Guaranteeing conformance and interoperability

The debugging and verification of components that result from the product development identified above follows a progression. We have characterized the progression into five major stages:

1. Transport Layer Verification
2. Protocol Verification
3. Basic Connection Testing
4. Advanced Connection Testing
5. Load Generation

Once project teams deliver the first generation hardware, they usually go on to fix bugs and implement enhancements that were not addressed in the first version due to time-to-market considerations. There is a continuous cycle of debugging and regression testing through the 5-stage testing procedure

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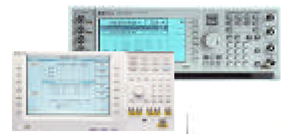
*3G Test Solutions*



## Component Test

- RF design libraries, signal generators, vector analyzers

## Base Station and Mobile Station Test

- Transmitter testers, power meters, mobile parametric test set

## RF Network Optimization

- Drive test solution

## RAN Infrastructure Development Test

- *3GTS (3G Test System)*

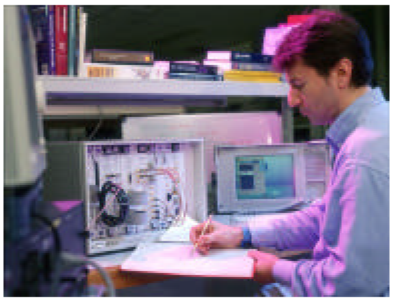
## Solutions and Services

- Consulting services, product and technology training

# 3G Test System (3GTS)

## *Product Features*

### *For Developers of Radio Access Networks*



**Multiple High-speed ATM Interfaces**

- 1.5 Mbs to 622 Mbs, supporting AAL-2, AAL-5

**Monitor, Simulate, and Emulate:**

- Node B, RNC, CN equipment
- Iu, Iub, Iur interfaces
- Transport, Control, and User planes

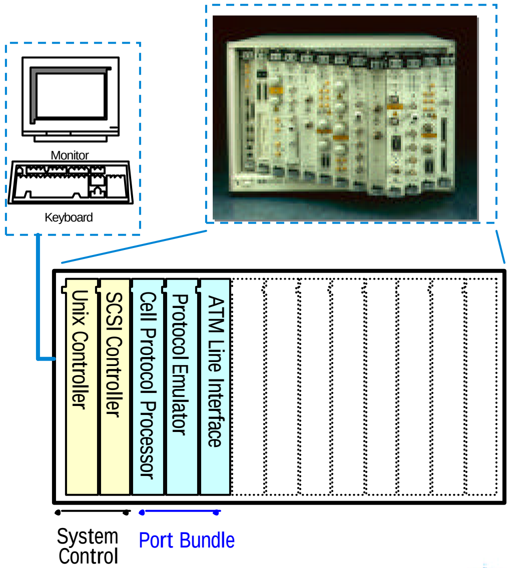
**Multi-channel, Multi-port, Multi-user**

- Simultaneous testing across interfaces of the complete 3G network

**Connection Verification**

- Simultaneous connections; Circuit and packet data delivery; Diversity; Handover

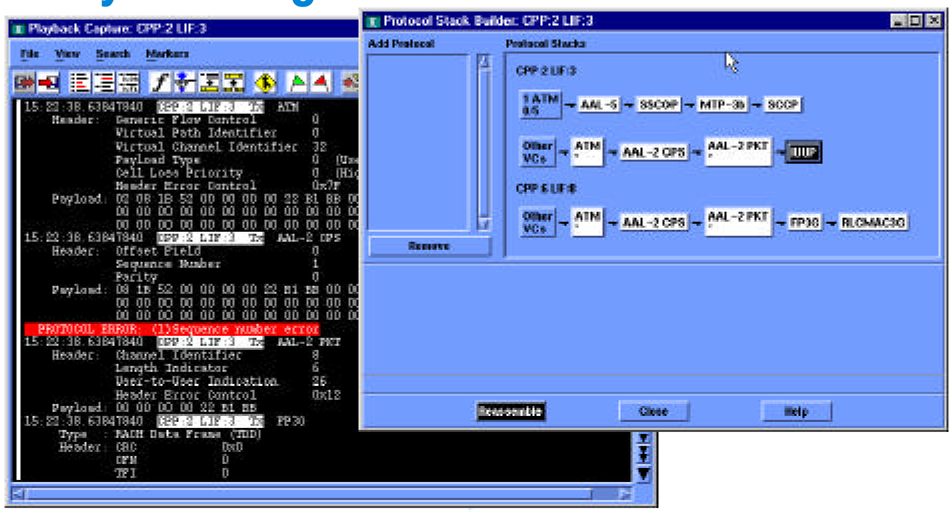
# 3GTS Hardware Platform




## Agilent Products

- **E4210B Form-13 Mainframe VXI Chassis**
- **E5161A Port Bundles:**
  - E4209B Cell Protocol Processor
  - ATM LIF (option from 1.5 Mb/s to 622 Mb/s)
- **E5162A Protocol Emulator**
- **E5160B UMTS W-CDMA Test Software**

# Agilent E5160B UMTS W-CDMA: Analysis using the GUI

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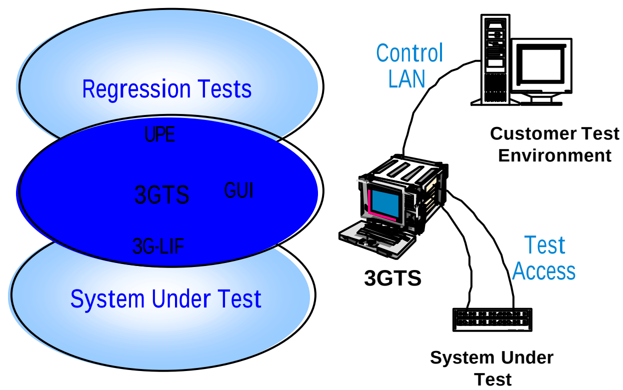
# 3GTS User Environment

**Open Test Methodology for Your Test Management System**

- Unrestricted test methodology
- Low-level protocol layer access
- High- performance operational interface
- Optical and electrical Interfaces from 1.5 Mbs to 622 Mbs

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## Part 2: Frame Protocol

### About Frame Protocol

- Where it is used; What it does
- Transport channels; transport blocks; frame formats

### Functions of FP

- Data transport; RNC flow control;
  Node B timing alignment

### Testing Issues

- Using 3GTS FP Emulation

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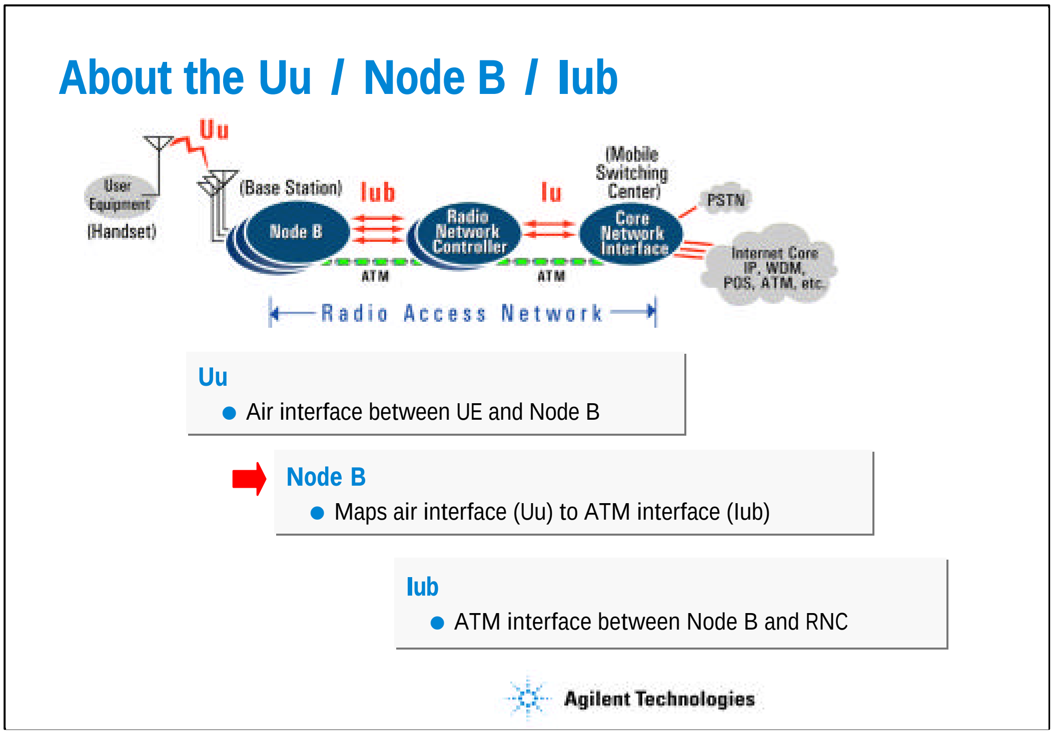
Frame Protocol (FP) is a Layer-1 protocol handled by the Node B (also called radio base station). FP provides an important synchronization function between higher-layer radio access protocols (for example, MAC, RLC) and the timing requirements of the radio transmission medium.

In this section, we will examine how the Node B translates air interface (RF) frames into FP frames. We will explain FP concepts, such as the TTI parameter, and node/channel synchronization. We will also provide examples of testing techniques designed to verify critical aspects of an FP implementation.




**Node B (also called the Base Station Controller or Radio Base Station)**

A cell refers to the geographical area covered by a "base station". The user communicates via one or more cells in order to achieve reliable access to the core network. In 3GPP terminology, the **Node B** is the network element that performs the radio base station function. There is one Node B network element per cell. It connects to the UE via the **Uu** (air) interface and to the RNC via the **Iub** interface. The Node B is the "gateway"between the User Equipment and the Radio Network Controller. It performs a translation function between the air (RF) interface and the wireline (Iub) interface.

While the RNC controls a number of Node Bs, and is largely responsible for handover decisions *between* cells, the Node B manages power control *within* a cell. For example, the Node B switches power from one directional antenna to another as the UE moves around within the cell.

Because the Node B sits between the wireless and the wireline parts of the radio access network, it is responsible for timing synchronization between two transmission media that have very different characteristics. Synchronization plays a role in both the **uplink** (UE to UTRAN) and **downlink** (UTRAN to UE) directions.

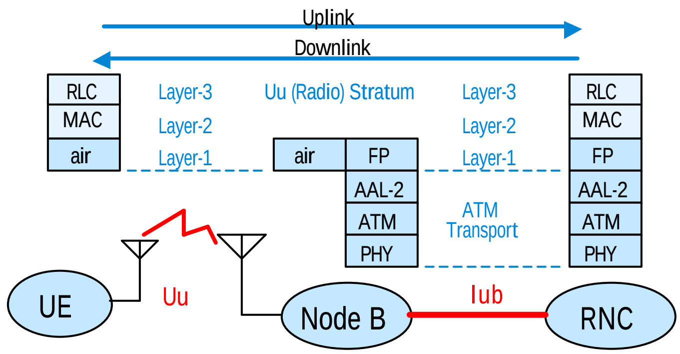
**Note 1** In 3GPP terminology, the Node B and the RNC are referred to collectively as the UTRAN (UMTS Terrestrial Radio Access Network). 3GPP is the 3rd Generation Partnership Project – responsible for co-ordinating the definition of UMTS/W-CDMA standards.

**Note 2** The 3GPP defines two radio access modes: FDD and TDD. Frequency Division Duplexing (FDD) uses different frequency bands for the uplink and downlink directions. Time Division Duplexing (TDD) interleaves uplink and downlink traffic over the same frequency band. FDD and TDD have slightly different synchronization requirements and procedures. Because FDD came earlier than TDD in terms of equipment development and network field trials, this application note will focus on FDD synchronization procedures.

## About Frame Protocol

**FP is a Layer-1 protocol over the Iub interface:**

- Air interface frames (Uu side) map to FP frames (Iub side of Node B)
- Performs a synchronization function between higher-layer protocols (RLC/MAC) and the radio transmission medium

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### About Frame Protocol

Frame Protocol (FP) is used to transport both user and control plane traffic over the Iub interface, between the UE and RNC. The protocol stack is shown above.

Frame Protocol acts as a synchronization interface between the higher layer radio protocols and the timing requirements of the radio transmission medium. The transmission characteristics of FP traffic over the Iub interface are directly related to the transmission characteristics of radio frames over the Uu interface.

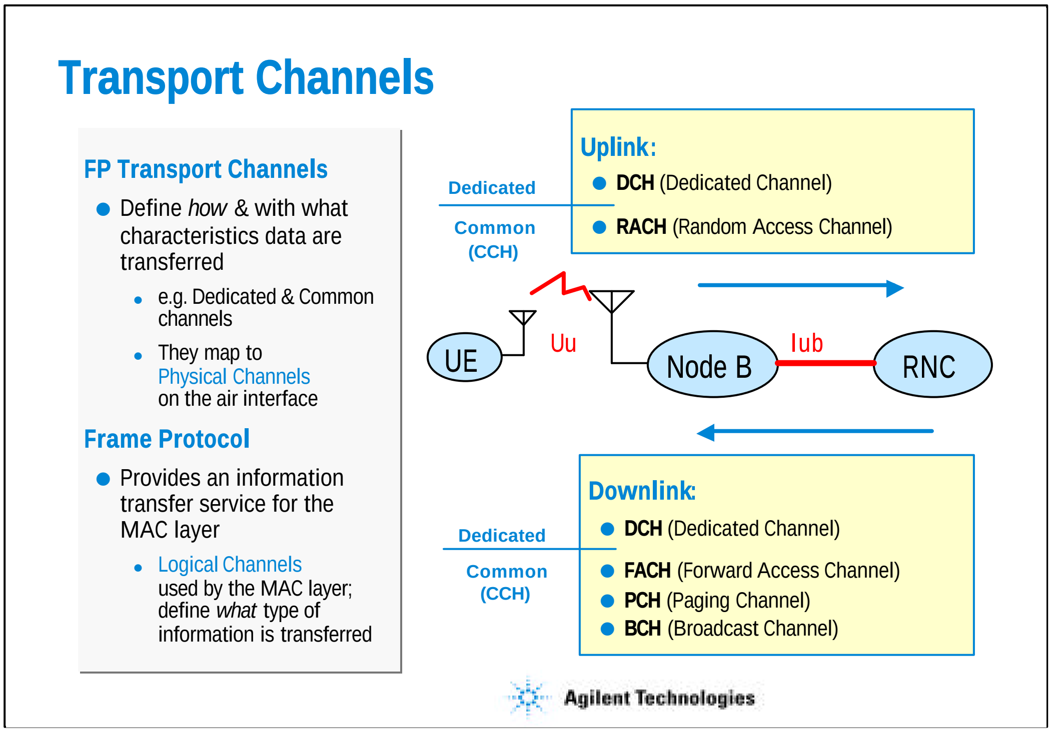
Air interface frames are sent at a constant 10 ms time interval, while MAC/FP layer frames are sent at 10, 20, 40, or 80 ms intervals (see section on Synchronization Parameters later).

**Note** FP is also sometimes referred to as Frame Handling Protocol (FHP) in earlier versions of the 3GPP documents.

### About Protocol Layers

In 3GPP terminology, the flow of messages between the UE and the UTRAN, required to control the radio access network, is called the **Uu Stratum**. [The flow of messages between the UTRAN and the CN (Core Network) is called the **Iu Stratum**.]

3GPP documents also use the term **radio interface** to refer specifically to Layers 1, 2, and 3 of the Uu stratum. FP is a Layer-1 protocol in the Uu (radio) stratum or radio interface. The radio interface protocols are transported by the ATM transport infrastructure [AAL/ATM (Layer-2) and PHY (Layer-1)].




### Transport Channels

Frame Protocol provides information transfer services to the MAC and higher layers. In 3GPP terminology, the term **transport channel** is used to describe *how* and with what characteristics data is transferred over the radio interface.

A transport channel is a uni-directional connection set up to provide a particular transport service for higher layers [*see next page for DCH*]. The most important characteristic is whether the channel is a common channel or a dedicated channel—that is, whether it is for use by multiple UEs or one particular UE. Other characteristics are related to the physical layer—whether transmission is FDD or TDD, the TTI, and so on.

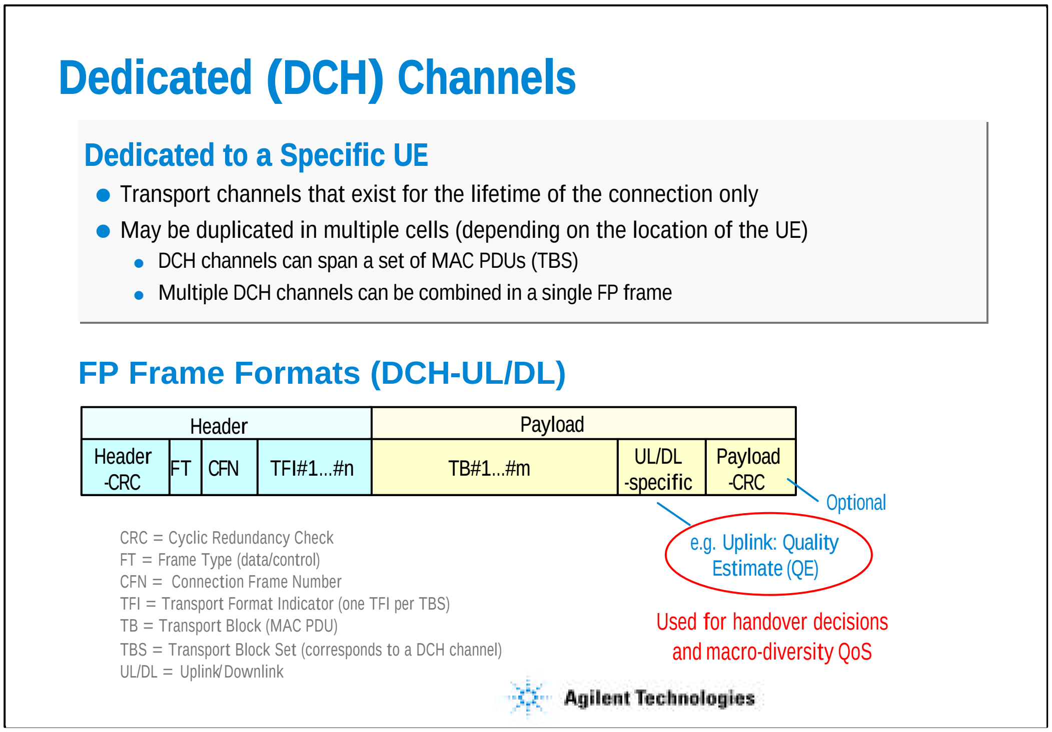
The diagram shows a typical cell, and the FP transport channels necessary for one 'call' to a UE. (A cell is the area covered by a particular Node B). Two basic categories of transport channel are:

- **Dedicated channels**: transport channels that exist for the lifetime of the call only, and may be duplicated in multiple cells depending on the geographical location of the UE; dedicated to a specific UE.
- **Common channels**: transport channels that are permanent and specific to that cell; *not* dedicated to a specific UE.

The common channels are used for signalling between the RNC and the UE to set up the dedicated channels used for data traffic.

### About Logical and Physical Channels

The MAC layer deals with **logical channels** that specify *what* type of information is transferred (for example, dedicated traffic, dedicated control, common control information). The air interface provides **physical channels** that are defined by specific characteristics of the RF encoding method (see Reference Information at the end of this application note).




There are two types of FP frames: Dedicated Channel (DCH), and Common Transport Channel (CCH).

DCH frame protocol provides the following services:

- Transport of Transport Block Sets (TBS) across the Iub (Base Station and Radio Network Controller interface) and Iur (Core Network and Base Station interface).
- Transport of outer loop power control information between the Serving Radio Network Controller (SRNC) and the Node B
- Support of transport channel synchronization mechanism
- Support of node synchronization mechanism
- Transfer of Downlink Shared Channel (DSCH) Transport Format Indicator (TFI) from the SRNC to Node B
- Transfer of receive timing deviation from the Node B to the SRNC

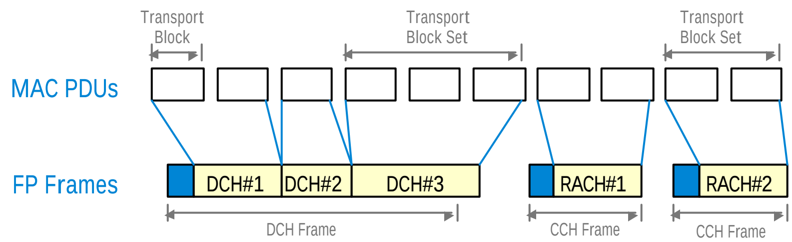
CCH provides the following services:

- Transport of TBS between the Node B and the Controlling Radio Network Controller (CRNC) for common transport channels
- Support of transport channel synchronization mechanism
- Support of node synchronization mechanism

## FP Functions: Data Transport

**Transport Block**

- Basic unit of information handed down from the MAC layer to FP
- Transport Block is also called MAC PDU
  - Multiple MAC PDUs can be multiplexed into a single FP frame
- Transport Block Set (TBS)
  - A set of MAC PDUs using the same transport channel
    for example, DCH or CCH (FACH, RACH)

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**Frame Protocol Data Transport**

The **Transport Block (TB)** is the unit of data from higher-layer protocols that is inserted into an FP data frame. It is often referred to as a **MAC PDU**. Multiple transport blocks from higher layer protocols can be multiplexed into a single data frame payload. A set of transport blocks that corresponds to one transport channel is called a **Transport Block Set (TBS)**.

The Frame Protocol Transport Format Indicator (TFI) parameter contains information about the composition of the payload, for example how many transport blocks it includes and the transport block sizes.

**Common channel data (CCH)** are not multiplexed into FP frames. In this case, the FP frame contains one TFI parameter and one TBS (CCH payload).

Multiple **dedicated data channels (DCH)** can be multiplexed into a single FP frame. In this case, there will be multiple TFIs in the FP frame header: one TFI per TBS. Each TBS corresponds to one DCH channel.

**Note** TFI values are not included in the FP specification. This information is vendor dependent. A TFI value that relates to one vendor's equipment may have an entirely different meaning for another vendor's equipment.

## Synchronization Parameters

### FP Node Parameters

- **TTI** (Transmission Time Interval)
  - The MAC-to-Layer-1 frame transmission frequency (UE & UTRAN)
  - TTI can be 10, 20, 40, or 80 ms
- **BFN** (Node B Frame Number)
  - Node B counts radio frame TTIs and assigns each frame a modulo 4096 (12-bit) identifier
- **RFN** (RNC Frame Number)
  - RNC maintains its own modulo 4096 (12-bit) radio frame count

### FP Frame Header Fields

- **CFN** (Connection Frame Number)
  - Modulo 256 (8-bit) count of the BFN (modulo 4096 for PCH)
  - Provides common Layer-2 frame numbering between UE and UTRAN
- **TFI** (Transport Format Indicator)
  - Describes the transport block length and transport block set size
  - *Not* standardized

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**Network/Node Parameters**

- **TTI (Transmission Time Interval)**

  The MAC/Layer-1 frame transmission frequency - the **TTI** - can be 10, 20, 40, or 80 ms. It is the transfer rate of MAC-layer frames within both the UE (MAC/air interface) and UTRAN (MAC/FP). **Note** that RF physical-layer frames are sent across the air interface at a constant rate of 10 ms, independent of the TTI.

- **BFN (Node B Frame Number)**

  The Node B counts the FP frame transmission periods (TTI) and assigns each frame a modulo 4096 (12-bit) identifier. This identifier is the **BFN**.

- **RFN (RNC Frame Number)**

  The RNC maintains its own 12-bit frame count. It also calculates the phase offset of the RFN relative to the BFN for each Node B connected to it (see description of node synchronization procedure later).

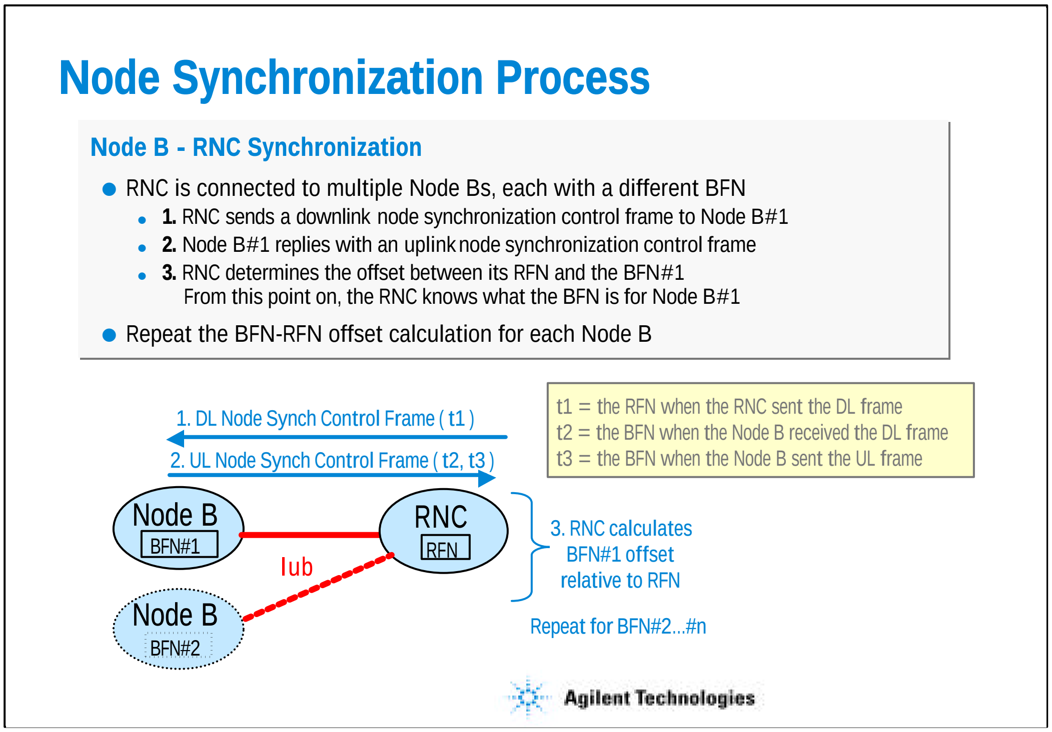
**FP Frame Header Parameters**

- **CFN (Connection Frame Number)**

  The CFN is associated with the same MAC (Layer-2) Transport Block Set at both the UE and UTRAN (Uu and Iub sides of the Node B). It is passed down to Layer-1, and indicates on which radio frame the first data for a particular channel was received in the uplink direction, or will be transmitted in the downlink direction. The CFN is the modulo 256 (8-bit) of the BFN (modulo 4096 for PCH, Paging Channel).

- **TFI (Transport Format Indicator)**

  This describes the transport block length and TBS size. This is represented as the local number of the transport format.




### Frame Protocol Synchronization

There are two types of synchronization control frames – node synchronization and channel synchronization.

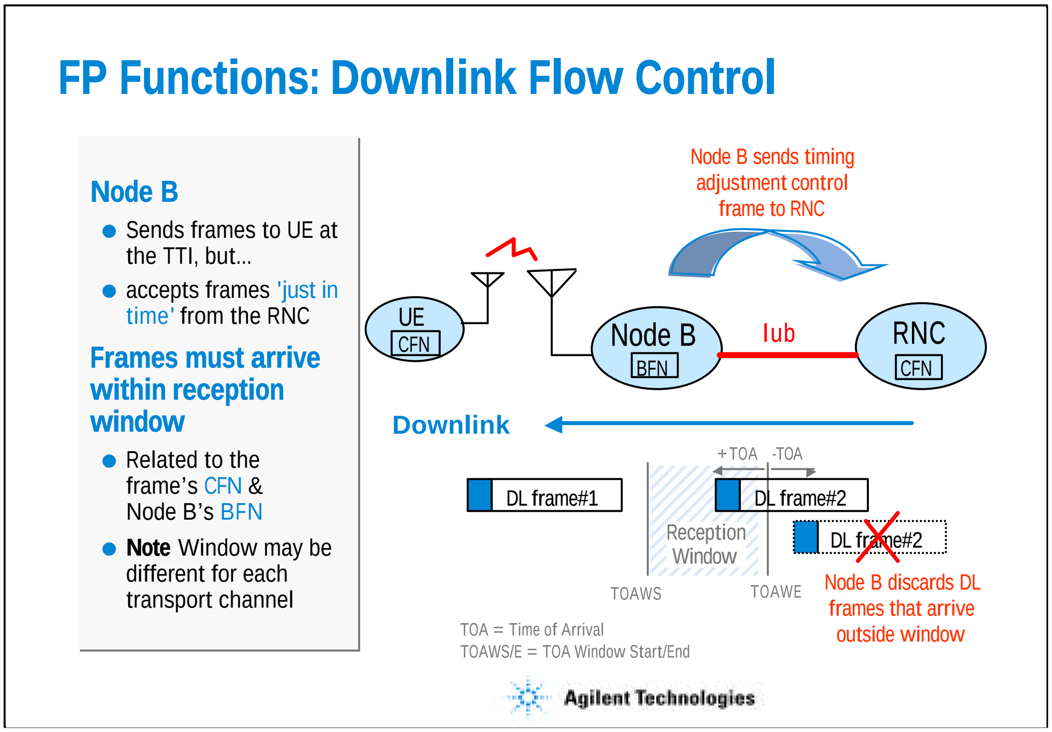
### Node Synchronization

The RNC- Node B synchronization process is based on the BFN of the Node B. Since different Node Bs have different BFNs, the RNC adjusts its timing (RFN) to that of each of its Node Bs. To perform this synchronization:

1. The RNC sends a downlink node synchronization control frame to the Node B, with its RFN as the only parameter.
2. The Node B replies with an uplink node synchronization control frame, which adds its own BFN at the time the frame was received, and also the BFN at the time it responded.
3. When the RNC receives the uplink node synchronization control frame, it determines the phase difference between its RFN and that of the Node B BFN. From this point on, the RNC knows that the BFN is for that Node B.

### Channel Synchronization

Channel synchronization follows on from node synchronization. Knowing the BFN means the RNC also knows the CFN used for any given channel for that Node B. This is because the CFN is the modulo 256 (4096 for PCH, Paging Channel) of the BFN. However, this is not enough information for the RNC to ensure that any frames it transmits to the Node B will be accepted, as each channel may have different characteristics and different sized reception windows. Therefore the channel synchronization process must be completed on each channel prior to data transmission over it.



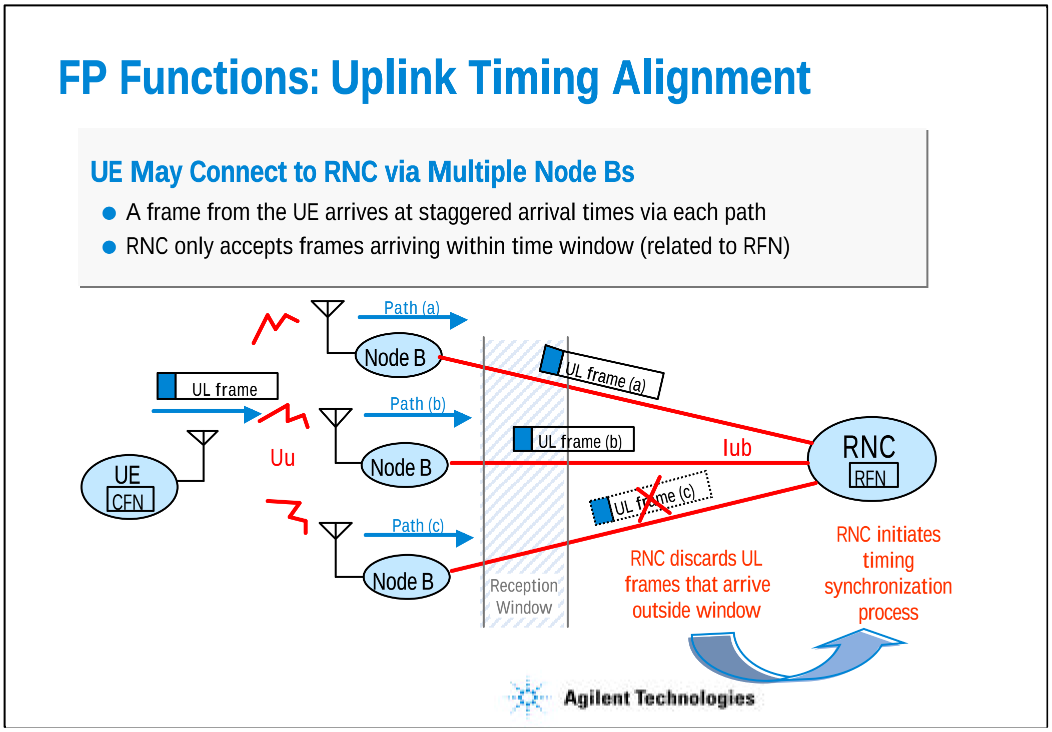

## Downlink Flow Control

In the **downlink** direction (RNC to Node B), synchronization is necessary simply for flow control. The Node B transmits frames towards the UE at the regular TTI. However, it accepts frames from the RNC in a 'just in time' manner. This creates some frame buffering requirements on the Node B. It also places limitations on how early or late the RNC can send frames to the Node B.

The RNC must send a frame to a Node B within a certain time window that relates to the frame's CFN. The frame must arrive at the Node B just before that slot commences. If it arrives outside the arrival time window, that is, it is too early or too late, the Node B discards the frame.

The Time of Arrival (TOA) parameter has a *positive* value if the frame arrived *before* the TOA Window End (TOAWE). It has a *negative* value if the frame arrived *after* the TOAWE.

When the Node B rejects a frame, it issues a timing adjustment control frame, indicating to the RNC the frame that was mis-timed and by what margin.



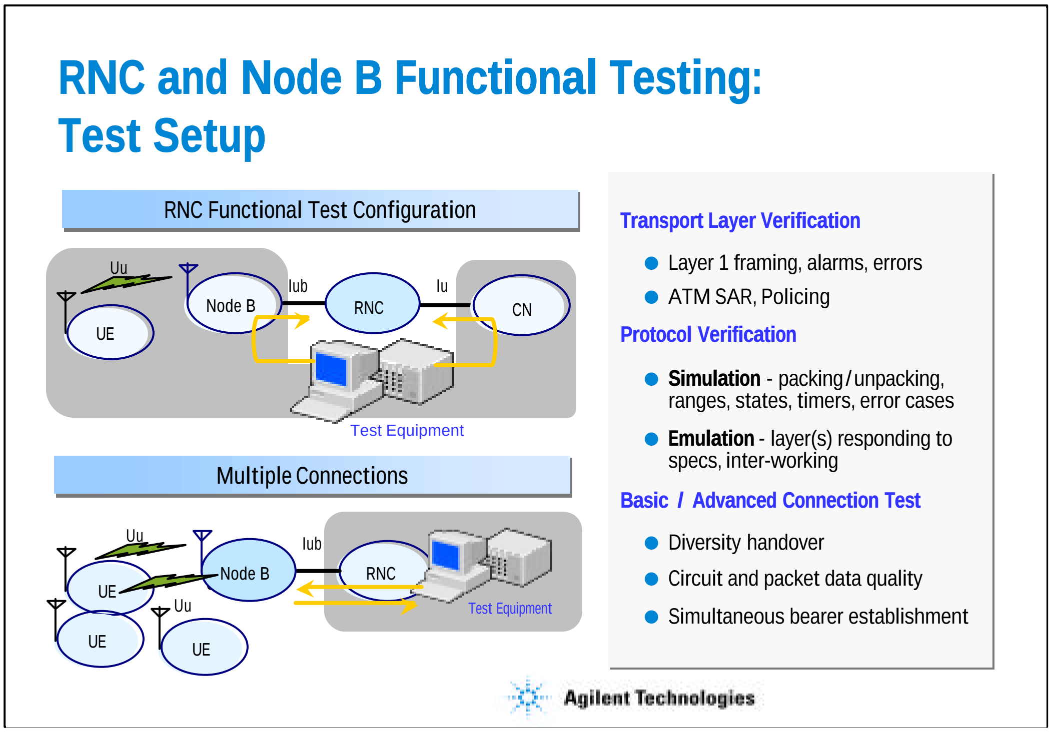

## Uplink Timing Alignment

In the **uplink** direction (Node B to RNC), flow control is not an issue. However, timing alignment between Node Bs is necessary because a UE may be transmitting to several
Node Bs at once. This occurs in soft handover (as the UE moves from one cell to another) and in macro-diversity (the UE transmits data over multiple Node B paths and the RNC accepts data from the path with the best QoS).

Depending on the location in relation to Node Bs, a frame from a UE could be received at the RNC from several Node Bs at slightly staggered arrival times. In order to be able to correctly identify frames with the same CFN on each Node B path, the RNC only accepts frames from the Node B(s) that arrive within a reception window for a particular CFN.

The RNC maintains its own RFN to do this (based on the BFN - see Node Synchronization, discussed later). If the Node B transmits a dedicated channel frame that falls outside the RNC's reception window, the RNC rejects the frame and attempts to re-synchronize with that Node B.

**Note** Uplink synchronization is necessary only for dedicated channels (DCH frames). Since common channels are specific to a certain radio cell, no duplication of CCH frames from multiple Node Bs in the RNC is possible.




**RNC and Node B Functional Testing: Test Setup**

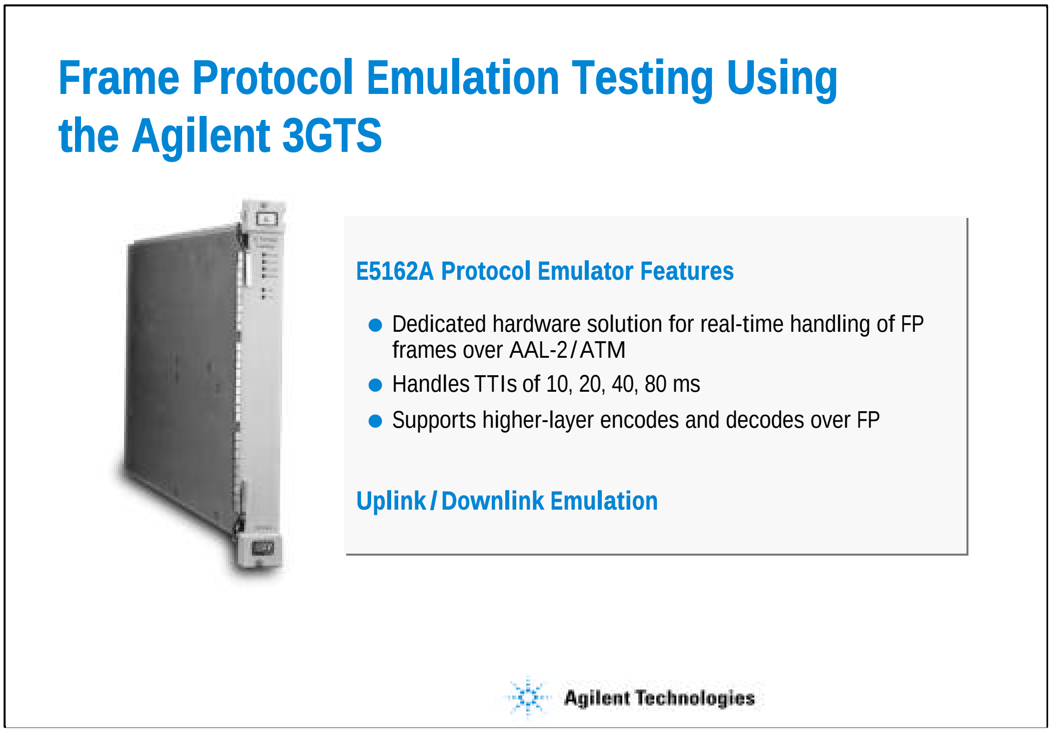
The first 3 stages of testing can all use a similar test setup. The basic procedure is to “surround” the device under test by connecting the test equipment to each type of interface. For example,

- Test the RNC by connecting the test equipment to the Iub and Iu interfaces
- Test the Node B equipment by connecting the test equipment to the Iub interface only

The basic requirements for the test equipment include:

- **Simulation** (stimulus/response testing)
  - Traffic generation (user data and control plane signalling)
  - Protocol analysis
- **Emulation** (protocol state machine testing)
  - Emulation of underlying protocol layers (for example, Frame Protocol) in order to fully test the higher layer protocols (for example, RLC/MAC)
  - Tester acts as a piece of equipment that is not available, for example, the Node B and CN functions required to fully evaluate the RNC under test

We will now look at some examples of how 3G RAN functions and performance are verified. We will focus on the role performed by the Node B in synchronizing the air interface (Uu) to the ATM interface (Iub).



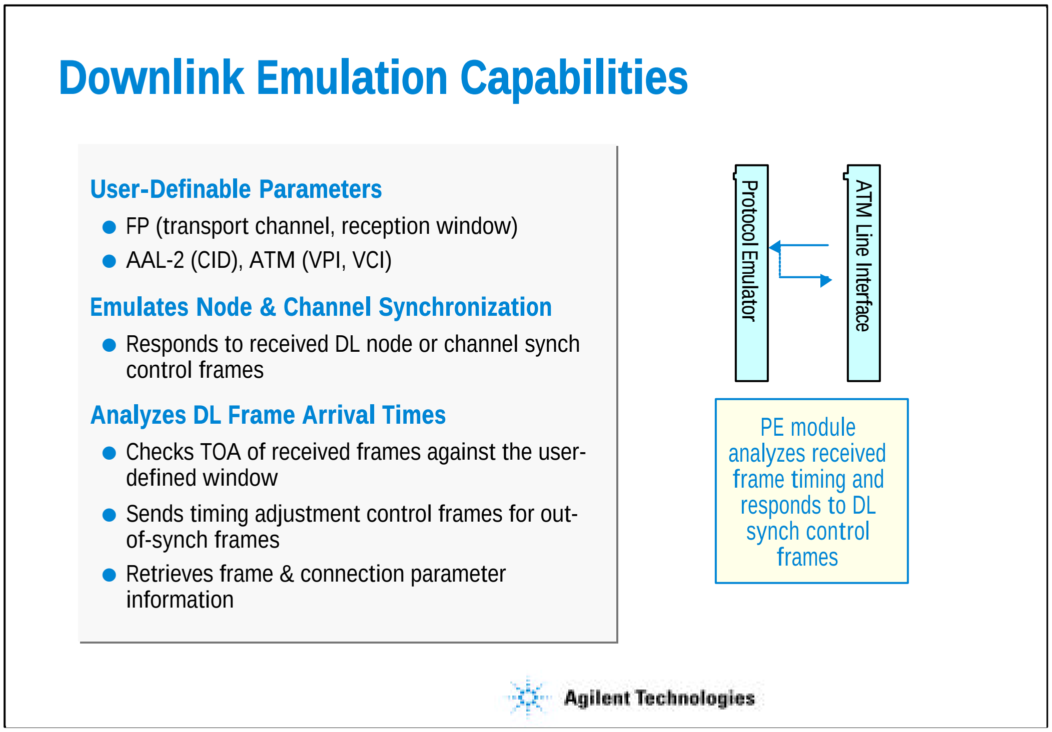

**FP Emulation Testing**

The Agilent E5160B 3GTS software application operates with the Agilent E5162A Protocol Emulator module to provide real-time FP emulation that can handle 10 ms TTIs. The product (currently) emulates the Node B only, performing three functions:

- DOWNLINK SYNCHRONIZATION: The emulation maintains a BFN, answers synchronization control frames from the RNC, and issues timing adjustment control frames as appropriate.
- DOWNLINK DATA TRANSPORT: Generates UPE events containing any valid data frames received from the RNC.
- UPLINK SYNCHRONIZATION: Synchronizes transmission of dedicated channel data frames according to its BFN so that they will be accepted by the RNC.

Note that uplink transmission of common channel data frames is asynchronous and so no emulation is necessary.

Of these three functions, the first two are combined into the DOWNLINK EMULATION, and the third is catered for by a number of functions termed UPLINK EMULATION. The 3GTS online documentation covers the detailed use of these functions.

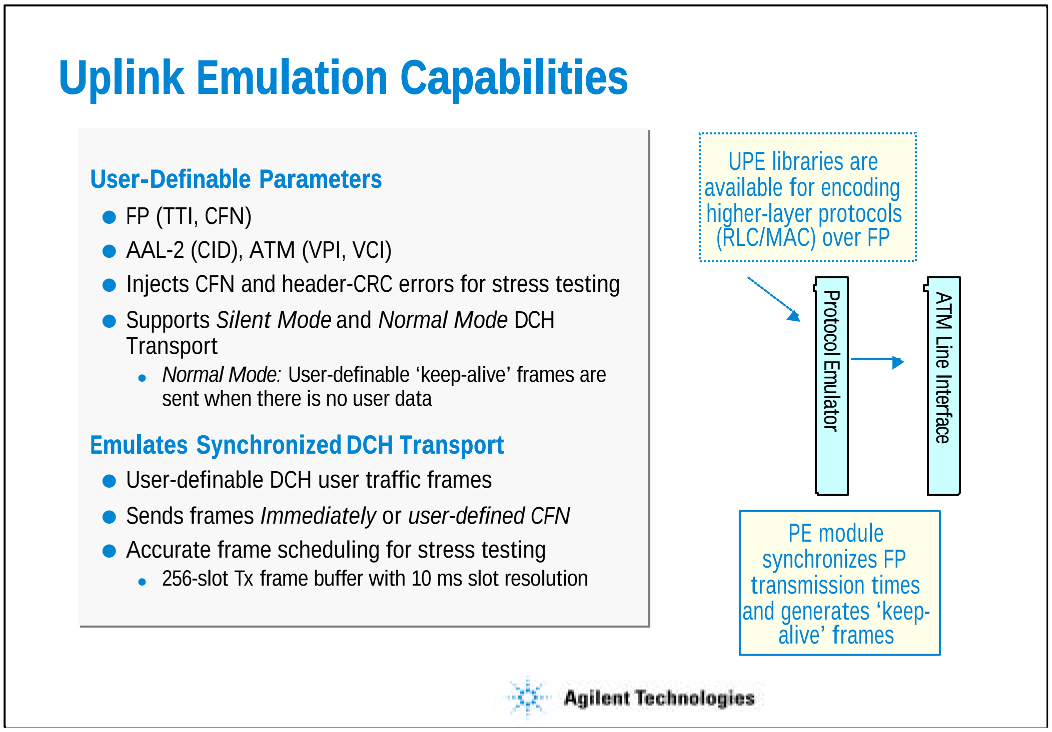



**Downlink Emulation**

The 3GTS can be used to emulate the Node B side of a downlink transport channel – for instance a FACH, PCH or DCH DL transport channel. FP transport channel, AAL-2, and ATM parameters can be defined by the user.

Whenever a node synch or channel synch control frame (from the RNC) is received by the DL emulation, the emulation automatically responds with an uplink node synch or channel synch control frame.

Whenever a data frame is received, the DL emulation checks that it has arrived within its reception window (specified by the window parameter). If it has arrived in the window, the user programming environment is notified of the reception of a valid data frame by a UPE event. The program can then retrieve and report on the frame and associated connection parameters.



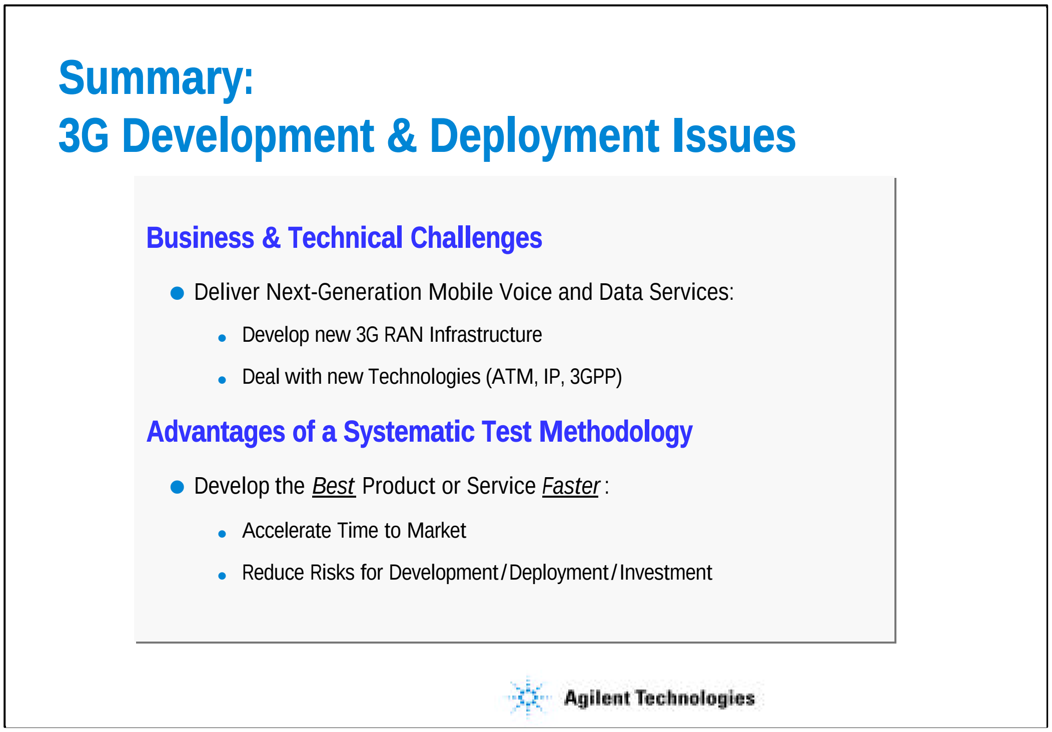

**Uplink Emulation**

The 3GTS can be used to emulate the Node B side of an uplink transport channel. The TTI and CFN for FP DCH transport channels, as well as AAL2 and ATM parameters, can be defined by the user.

The emulation supports two modes of DCH UL transport channel operation– *silent mode*, where if there is no traffic from the user, no data frames will be sent to the RNC, and *normal mode*, where in the absence of user traffic, a ‘keep alive’ or ‘empty’ frame must be transmitted. This empty frame could be used by the RNC to calculate handover of the dedicated channel between cells, etc.

The UL emulation also generates *user traffic* DCH UL frames as opposed to the automatically generated empty frames. Transmission time can be immediate or at a particular CFN transmission slot (10 ms interval) for that frame.

Synchronized transmission involves buffering frames requested for transmission by the user until a valid reception window is open in the RNC. That is, the user-requested CFN must match the current BFN (which is in turn synchronized to the RNC’s RFN by the node synchronization procedure).




**Conclusions**

Manufacturers and service providers are racing to develop 3G wireless systems to support the exploding demand for global, transparent wireless voice and data services. 3G systems will provide increased user capacity, mobile data transmission and Web access at rates of up to 2 Mb/s, and support for new multimedia wireless devices.

To deliver these advances, however, the RAN must be able to manage a wide range of tasks for each 3G user, including access, roaming, transparent connection to the public switched telephone network and the Internet, and Quality of Service (QoS) management for data and Web connections.

A systematic testing methodology allows 3G manufacturers to speed development of RAN software and equipment, such as base station and radio network controllers, and core network interfaces. Wireless service providers can use a similar testing strategy for independent evaluation of vendor equipment to guide purchasing decisions, and to evaluate field trial networks.

**3G Test System**

www.agilent.com/comms/3GTS

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**Protocols**

AAL-2 = ATM Adaptation Layer, Type 2 (for voice and low-bit-rate data)

AAL-5 = ATM Adaptation Layer, Type 5 (for packet data and ATM signalling)

ALCAP = 3GPP Adoption of Q.AAL-2 Signalling Protocols

ATM = Asynchronous Transfer Mode

FP = Frame (Handling) Protocol; cch/dch = control/data channel

GTP-u = GPRS Tunneling Protocol (Iu)

IP = Internet Protocol

Iu UP = Iu User Plane

M3UA = SS7-MTP-3-User Adaptation Layer

MAC = Media Access Control

MTP-3b = Message Transfer Part Level 3 (Broadband)

NBAP = Node B Application Protocol

NNI = ATM Network to Network Interface

PDCP = Packet Data Control Protocol

RANAP = Radio Access Network Application Part

RLC = Radio Link Control

RNSAP = Radio Network Subsystem Application Part

RRC = Radio Resource Control

SCCP = Signalling Connection Control Point

SCTP = Stream Control Transmission Protocol

SSCF = Service Specific Coordination Function

SSCOP = Service Specific Connection Oriented Protocol

STC = Signalling Transport Converter

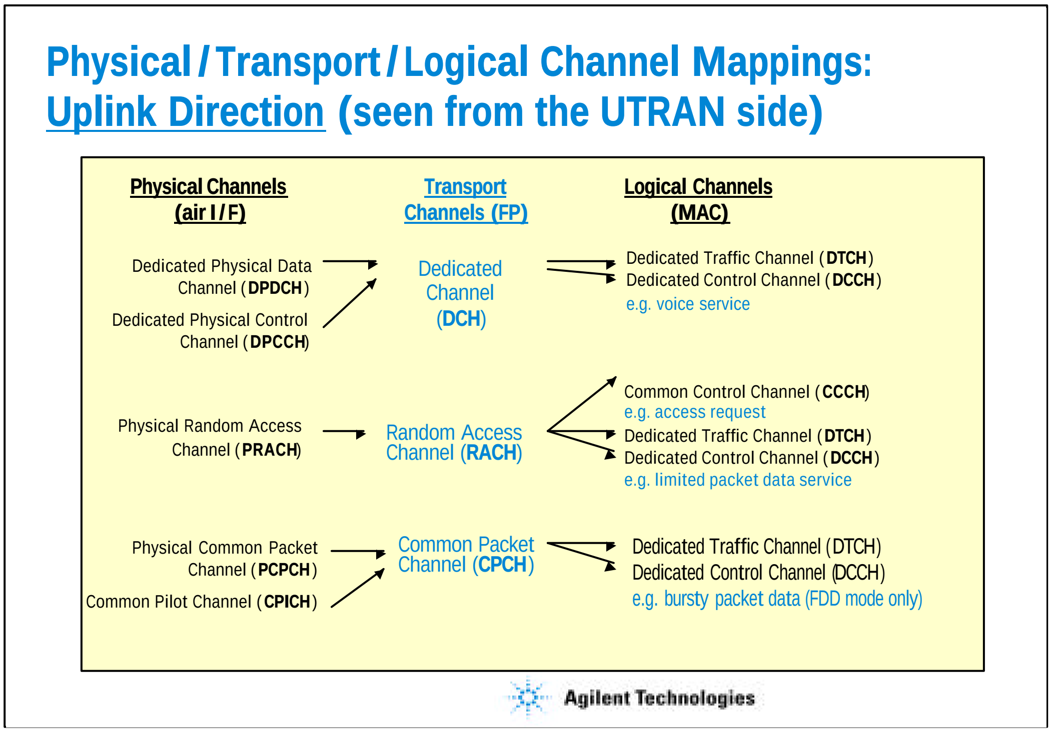
UDP = User Datagram Protocol

UNI = ATM User to Network Interface

# Reference Information

**Topics:**

- Mapping of radio interface channels: Physical / Transport / Logical
- Uu (radio) stratum protocol encapsulations

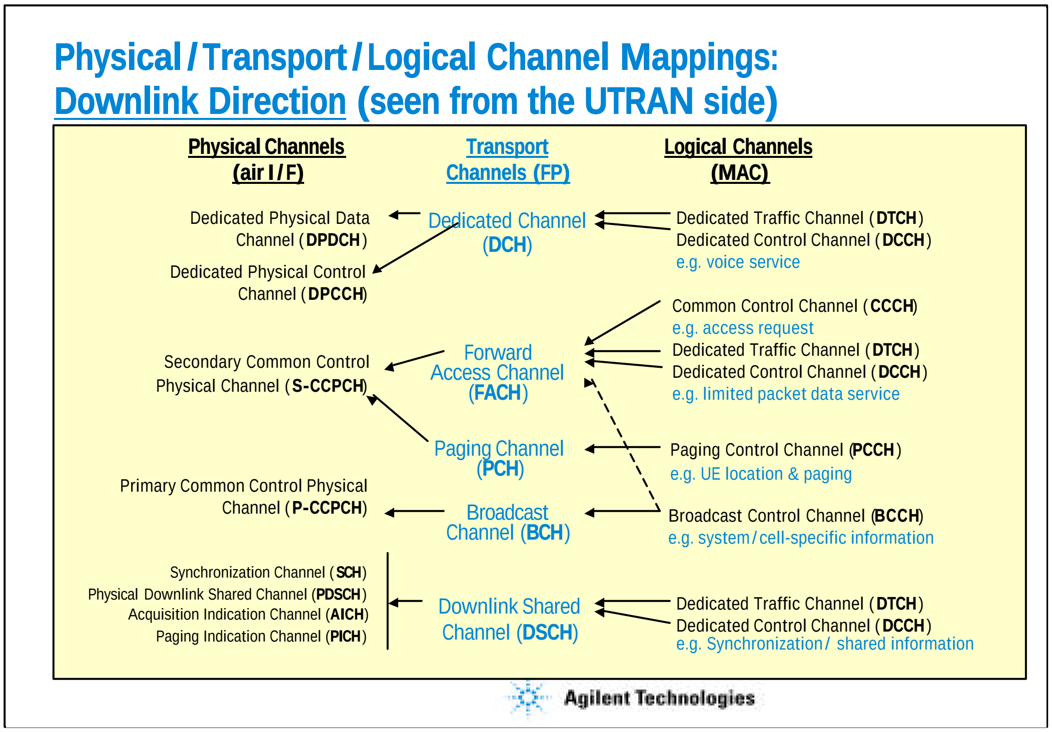



## Physical/Transport/Logical Channel Mappings

The FP transport channels provide a mapping between physical channels on the air interface, and logical channels at the higher protocol layers (MAC).

- The MAC layer deals with **logical channels** that specify what type of information is transferred (e.g. dedicated traffic, dedicated control, common control information).
- The air interface deals with **physical channels** that are defined by specific characteristics of the RF encoding method. In FDD (Frequency Division Duplex) mode, physical channels are defined by code, frequency, and (uplink) relative phase. In TDD (Time Division Duplex) mode, physical channels are defined by code, frequency, and time-slot.

This diagram shows the information transfer services (**transport channels**) that Frame Protocol provides in the uplink direction. Commonly-used logical channels are DCH and RACH.



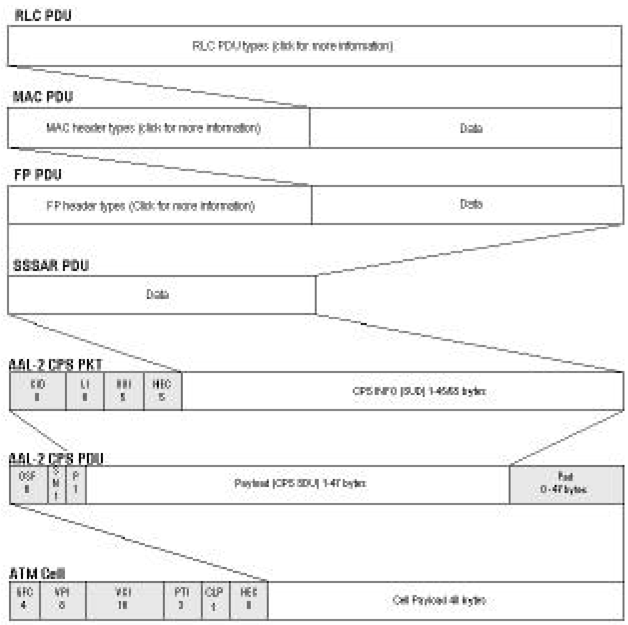

**Physical/Transport Channel Mappings** (cont.)

This diagram shows the information transfer services (**transport channels**) that Frame Protocol provides in the downlink direction. Commonly-used logical channels are DCH, FACH, PCH, and BCH.

# Uu (Radio) Stratum Protocols

**Extract From 3GTS Online Help**

- Reference information




**Note:** All field sizes are measured in bits unless indicated otherwise.

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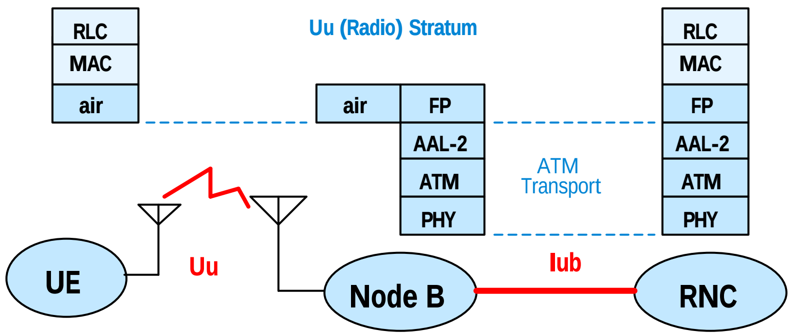
The 3GTS provides extensive online help, including operation instructions, programming references, and technology reference information on 3GPP protocols.

This diagram shows how higher-layer protocols (RLC/MAC) are mapped into FP frames. It also shows how FP frames are mapped into the AAL-2 (CPS PKT and PDU) layers. Note that the AAL-2 SSTED error checking layer is not used for encapsulating FP.

# This completes the *Frame Protocol* Overview






**REFERENCES**

| | |
|---|---|
| Synchronization in UTRAN | 3GPP 25.402 |
| FP DCH spec | 3GPP 25.427 |
| FP CCH spec | 3GPP 25.435 |