Simulation Testing in Mobile Networks Protocols and Applications Perspective

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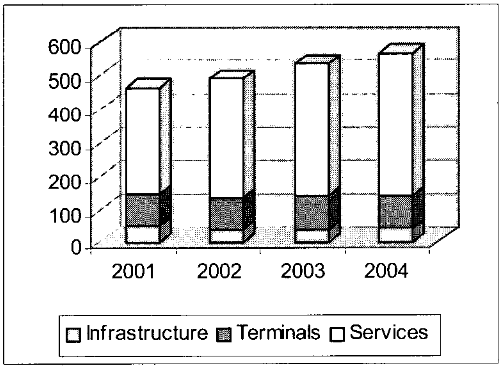
Abstract

The mobile industry is waking up to the reality that customers buy 'services', not technology. Thekey is to deliver a variety of differentiated services today and improve them as the advanced technology becomes available. In the increasingly data centric world of the future, the emphasis will be on the provision of a range of services audio, video, data and multimedia and of course speech.As we move closer to the realization of these mobile services in the conglomeration of converged networks, new challenges are being faced by the technology and application developers as well as the service providers to design, test and integrate new products and services. Functionalities like availability, scalability, performance and compatibility have become more important. This paper discusses the new test paradigms in the mobile networks, both from the applications and the protocols perspective.

INTRODUCTION

The global acceleration in mobile communications has been astounding. The mobile subscribers base has reached 1 billion mark worldwide, up from just 11 million in 1990. The second generation mobile networks viz GSM (Global System of Mobile Communication), IS-136 and IS-95 have stabilized, the 2.5G is getting deployed with GPRS (General Packet Radio Service) and the 3G (Third Generation) with UMTS (Universal Mobile Telecommunications System), EDGE (Enhanced Data Rate for Global Evolution) over GPRS (General Packet Radio Service) and CDMA1X (Code Division Multiple Access) is yet to pick up. There will be a mobile market of 600 billion USD (US Dollars) worldwide by 2005 says Dec2002 Gartner report [2]. The major share of which would come from the services market as shown in Figure 1.

In the process of convergence of existing circuit switched networks with the IP (Internet Protocol) networks, the intelligence of call processing has shifted from the core to the edges of the networks. The bandwidth in the broadband backbone is getting shared between the control signalling and the bearer data, possibly affecting the quality of service. A New Port Inc report [10] says that 52% of the applications failed to scale as planned and users are not tolerant of delays more than 10 seconds. The UMTS specifications are getting complex day by day and there is a need to verify the implementations for each new revision. As about 30-50% of the product development cycle is spent on verification and validation, all these factors have compounded the need to have robust and efficient test methods used during design, implementation and deployment phases.



[Fig 1] Worldwide Mobile Market (In billions USD)

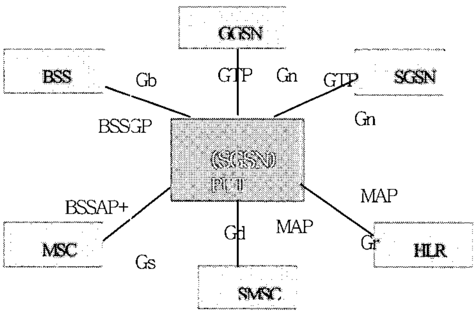
Challenges in moving ahead: -

1. Interoperability of different networks/technologies.
2. Convergence of voice and data networks, mobility and internet.
3. Backward compatibility Mobile devices and the networks.
4. Creation of killer applications over the existing infrastructure.
5. Increasingly sophisticated network elements.
6. Core network migration from circuit switched to packet switched.
7. Quality of service (QoS) issues.
8. Integration of new services (packet data and mobile multimedia services - MMS) into existing user interface paradigms.

SIMULATION TESTING IN MOBILE NETWORKS-What, Why and How

Testing in mobile networks has several facets ranging from protocol and conformance testing to inter-operability and performance testing in the field after deployment. In most of these test methods, there is often a need to have the complete network environment, which includes all the network elements that interactwith the Product Under Test (PUT). This is not only expensive but is also sometimes unavailable due to change in technology at high pace, different standards in different geographies and concurrent development by various vendors. At the same time it has been felt that not all the network functionalities are required simultaneously and abnormal behaviours are also required to be generated, hence arises the need for simulation of network elements. This allows the availability of the complete test bed inside the laboratory thereby reducing test cycles and increasing productivity.

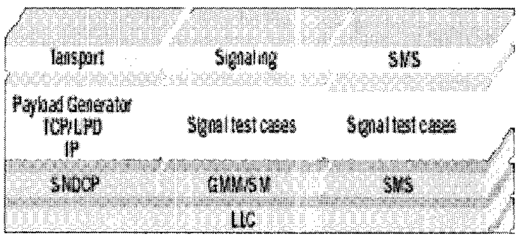
Protocols Perspective



[Fig 2] Simulation bed for SGSN

As an example, when we are testing the protocols and interfaces of an SGSN (Serving GPRS Support Node) in a GPRS network, all the nodes that interact with SGSN in a typical GPRS network [8] need to be simulated. i.e. the BSS (Base Station System), GGSN (Gateway GPRS Support Node), other SGSN, MSC (Mobile Switching Centre), SMSC (Short Message Service Centre) and HLR (Home Location Register). There can be different protocol stacks running on the different interfaces for the user and the control plane as shown in Figure 2. The test environment may require synchronization or master control above all these simulated entities for controlling and test result reporting.

However if the scope of test is just one protocol, then only the corresponding nodes are required. For e.g. while testing GTP on SGSN, only the other SGSN and GGSN need to be simulated. Also while performing white box testing for a protocol layer, which is the part of a stack on an interface, it may be required to simulate the upper layer functionality. For eg when GTP layer running on SGSN Gn interface is the Implementation Under Test (IUT) then GMM, SM and MAP_IW functionalities are required to trigger the GTP IUT upper layer interface. [Refer to GTP Case Study mentioned ahead]



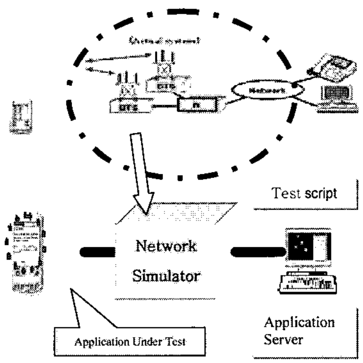
[Fig 3] Gb interface simulation

In case there is a protocol layer in the PUT stack, which is interacting with its peer not present in its adjacent node then the functionality of the peer protocol can be simulated over the protocol stack of the just adjacent node. To elaborate, the NAS (Network Access Server) layers (as they are called in UMTS) [5] such as GMM (GPRS Mobility Management) and SM (Session Management) in GPRS can sit over BSS stack to simulate the complete Gb interface for SGSN testing as shown in Figure 3. Hence the simulated entity is not just BSS but also contains the functionality of MS i.e. GMM, SM or SMS protocols.

Applications Perspective

Mobile applications include all those services in which it appears to the users that they are using the mobile communications network purely as a pipe to access messages or information. The simulation approach for applications testing has different characteristics as the emphasis is primarily on the user plane characteri- stics or the bearer capability of the network. Here the entire network needs to be simulated as a whole that provides the signalling and the transport to the application packets between the client and the server [1]. There are two basic approaches to simulate the network behaviour for application testing as mentioned below: -

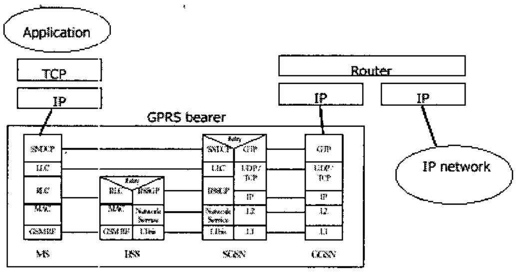
1. Complete Network simulation including the RF interface This includes the complete simulation of BSS and Core network elements to establish, maintain and delete the connection/session between the device and the server. As shown in Figure 4, , the client application running on a handheld containing the wireless modem, talks to the Network Simulator Box on the Radio Frequency (RF) interface and Simulator Box talks to the application server on the IP/serial interface. In this way an end-to-end push or pull application can be triggered with the simulator acting as the mobile network bearer.



[Fig 4] Complete Network Simulation

2. Network behaviour simulation on IP level This approach captures the IP packets between the client and the server and introduces the network related interruptions or error scenarios. All these steps are user configurable and the device can be connected to the simulator box through a serial or Ethernet interface. This makes it a much simpler and cost-effective

method of validating the mobile applications behaviour subjected to erroneous network conditions. The GPRS bearer shown in Figure 5can be thought to be replaced by the simulator box and the end-to-end application can be functioned on the IP level.



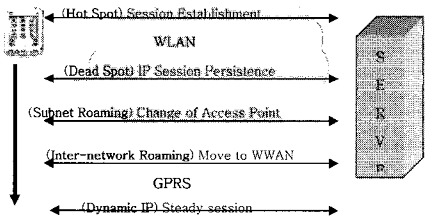
[Fig 5] GPRS User Plane Structure [9]

The simulation should necessarily be able to introduce all the network communication related delays and error scenarios for testing the suitability of the application for the mobile network interface. A typical mobile application needs to be verified for the quality, reliability and throughput etc as defined in the 3GPP standard specifications [3]. An example of GPRS Quality Of Service (QoS) requirements is shown in Figure 6.

In an inter-network roaming scenario, there may be more than one type of network involved when the application persistence is being verified. A typical scenario can be a download happening through the Wireless Local Area Network (WLAN), which gets interrupted when the user moves out of coverage, and the session should resume after the device connects to the GPRS Wireless Wide Area Network (WWAN). In such a case both the WLAN Access Point(s) and the GPRS network need to be simulated simultane- ously of connection to the GPRS WWAN [7].

Delay Class	Packet Size			
	128 octet		1024 octet	
	Mean Transfer Delay (sec)	95 percentile Delay (sec)	Mean Transfer Delay (sec)	95 percentile Delay (sec)
1. (Predictive)	0.5	1.5	2	7
2. (Predictive)	5	25	15	75
3. (Predictive)	50	250	75	375
4. (Best Effort)	Unspecified			

[Fig 6] GPRS QoS - Delay Class Profile

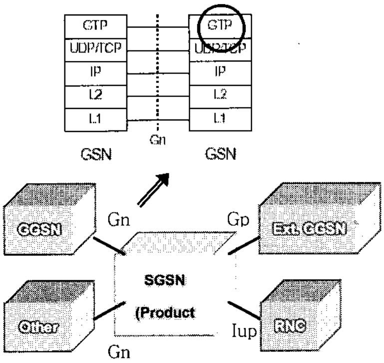


[Fig 7] Inter-network roaming scenario

Figure 7 shows a scenario in which the mobile user moves from across a WLAN encountering Dead Spots (Out of coverage) and change of Access Point (Subnet Roaming) and finally switches the connection to the GPRS WWAN maintaining a steady session. There can be scenarios in which more than one mobile service provider can be present in an area, which would require multiple Public Land Mobile Networks (PLMNs) to be simulated.

GPRS TUNNELLING PROTOCOL(GTP) TESTING A Case Study

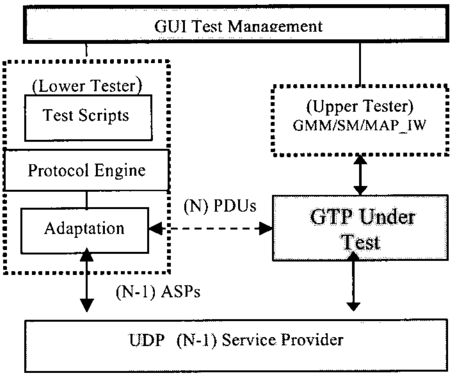
GPRS marks the introduction of packet transmission in cellular networks. It allows efficient use of radio resources, volume based charging, fast set-up time and seamless integration with both the existing data networks and the GSM infrastructure. GTP is the protocol used between GSNs (GPRS Support Nodes) in a GPRS network to tunnel the multiprotocol packets to and from the external IP network. This case study makes an attempt to focus on the simulation approach adopted to test GTP stack running on the SGSN including the user and control plane. The testing was carried out as per 3GPP TS 29.060 v 3.12 [4].



[Fig 8] GTP Test Environment

The network elements, which are required to be simulated, are GGSNs (Gn and Gp interface), RNC (Iup interface of UMTS architecture R3) and the other SGSNs (Gn interface), which interact with the SGSN through GTP. These simulated entities act as the Lower Tester (As per terminology of Tree And Tabular Combined Notation TTCN) [6] for GTP Implementation Under Test (IUT) in which the peer GTP is simulated.

Figure 9 shows the architecture of the test solution used for testing the GTP IUT. The Upper Tester acts as the GTP user (like GPRS Mobility Management - GMM or Inter-working Mobile Application Protocol - IW_MAP protocol layers). The Upper and Lower Testers can have a common control for the test executor.



[Fig 9] Simulation Architecture

Challenges in simulation development

- Simulation test engine requires

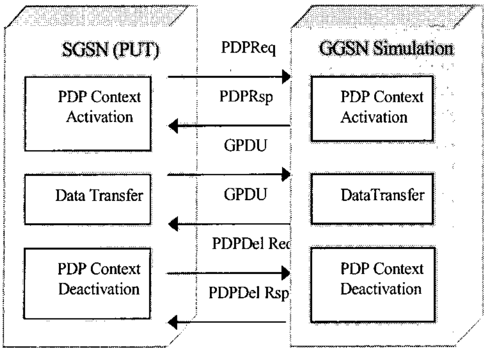
complete encode/decode of GTP-u (GTP User) and GTP-c (GTP Control) messages.

- Separate test engine implementations for GGSN, SGSN and RNC GTP simulation.
- Maintenance of PDP (Packet Data Protocol) contexts and tunnels for each user.
- Capability to generate erroneous message sequences and incorrectly encoded messages.
- Capability to simulate several networks elements simultaneously.

Figure 10 shows a typical test scenario in which the tunnel management (PDP Context Activation and Deactivation) and data transfer capabilities of the GTP IUT (SGSN side) are tested. This scenario occurs when a GPRS attached mobile user tries to establish a data session with the network. A PDP Context Activation Request from the Upper Tester (acting as GMM) triggers a PDPReq (Shorthand notations have been used for the messages not as perthe standard) message to be sent to the GGSN. The message is decoded and validated at GGSN as per the encoding rules and the expected parameter values set by the test executor. If the validation is successful a PDPRsp message is sent from the GGSN to the PUT with the tunnel ids for user and control plane. A tunnel should be successfully created between PUT and GGSN and appropriately indicated to the Upper Tester.

[Table 1] PROTOCOL TEST COVERAGE

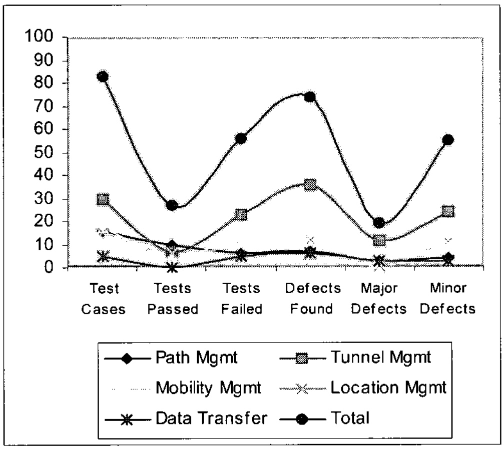
1. Functional Testing a. Tunnel Management. b. Path Management. c. Mobility Management. d. Location Management. e. User Data Transfer f. Version Negotiation g. Interaction between GTP-u and GTP-c. h. Tunnel Multiplexing on UDP (User Datagram Protocol) Paths 2. Interoperability testing - Inter-working with peer GSNs on different platforms.	3. Protocol Error Handling and validations a. Unknown and erroneous headers. b. Missing or invalid mandatory elements. c. Handling too short packets. 4. Performance Testing a. Number of tunnels supported simultaneously. b. Number of PDP Activations per second. c. Maximum speed of user data transfer per tunnel or per port. d. Quality of service parameters on each tunnel.



[Fig 10] GTP Test Scenario

Data integrity testing is performed using unique IP test packets that allow the Performance Test Suite to measure packet latency, out-of-order sequences, and bit error payload tests in each tunnel. GTP Protocol Data Unit (GPDU) transfer from both ends can be validated at different QoS settings(throughputs etc). Connection performance statistics can be provided for each tunnel to record the inter-access delay and response times. A number of logical tunnels need to be multiplexed on a single path and several paths can be maintained to enhance the capacity. Each path his it's own path management messages (Echo Request and Echo Response) to perform the heartbeat continuously checking the status of the path.

The mobility management messages are control plane messages that are sent between GSNs at the GPRS Attach and Inter SGSN Routing Update procedures. The optional Location Management messages are defined to support the case when Network-Requested PDP Context Activation procedures are used and a GGSN does not have an SS7-MAP interface. GTP is then used to transfer these messages between GGSN and the GTP_MAP converting GSN.



[Fig 11] GTP Test Results

The test results shown in Figure 11provide the number and classification of defects found during the functional GTP testing (This does not include performance and interoperability testing). Maximum numbers of defects were detected in GTP Tunnel Management procedures that were mainly bugsin encoding/decoding of the information elements of GTP messages and error handling. It becomes quite easy to detect the error handling defects in the simulation approach as the protocol finite state machine is essentially driven by the message sequence defined in the test script. Also the parameter values and the encoded buffers (HEX Dumps) of the messages sent to the PUT can be altered any time during the test. With an interactive test command interface the control of test execution can be controlled or altered during the execution of the test. Based on the message received, the next message to be sent can be parameterised. Test automation can also be provided to compare and capture the received message buffers or parameter values with expected ones.

This simulation test approach provides flexibility, modularity and faster time to market advantage as the test bed development can be carried out in steps (new messages can be plugged-in as per the test specifications) and the same framework can be customized to simulate different network elements. The adaptation provides the abstraction to the underlying service provider its protocol and the vendor specific application-programming interface (APIs). A standard (like TTCN) or a proprietary test language interface can be sued at the user level. The idea is to minimize the programming complexities for the test executor and enable him/her to focus on the protocol or domain functionalities.

GPRS APPLICATION TESTING - A Case Study

Whereas today's wireless applications tend to be text oriented, the high throughput offered by GPRS will finally make multimedia content, including graphics, voice and video practical. This case study describes the simulation approach for testing a typical GPRS application, which provides the mobile user access to the corporate database enabling query, update and text messaging functionalities.

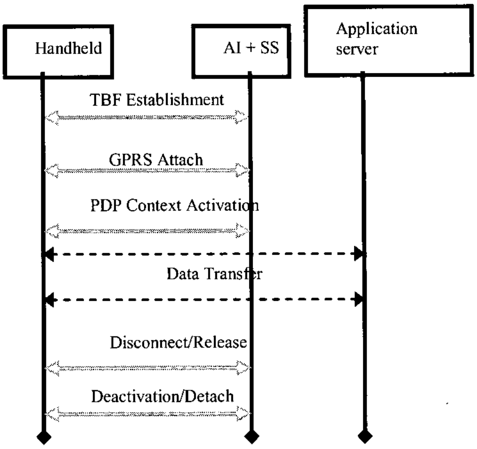
The test methodology of simulating the complete network including the RF interface was adopted. The Simulation Subsystem (SS) as shown in Figure 13 acts as the BSS providing RLC/MAC control and data block signalling. It also provides GPRS Radio Resource (GRR) and GRRMM Service Access Points (SAPs) in the form of APIs (Windows based) through General Purpose Interface Bus (GPIB) remote connectivity.

The dummy protocol stack is essentially simulating the SGSN and GGSN functionalities. It enables the device to GPRS Attach; establish the PDP Context providing the basic platform for the application to be launched. The inherent advantage with this architecture is that the same deployment can be used for protocol verification of the handset stack with suitable test scripts running on the simulated entities.

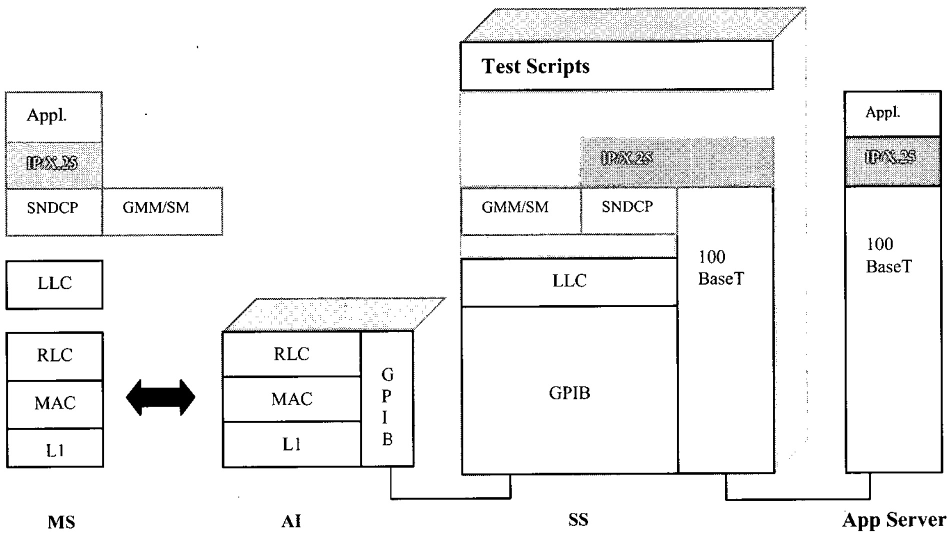
Simulation Highlights

1) GPRS RF access interface

2) Global RF configuration parameters
   a. Cell Parameters
   b. Channel Parameters
   c. Location Area Identity Parameters
   d. SIM Parameters
3) Simulations for LLC (Logical Link Control), GMM, SM and SNDCP (Subnetwork Dependent Convergence Protocol) protocol functionalities.
4) Packet Routing and Tunnelling
5) Quality Of Service negotiation
6) 56 Kbps net data throughput.
7) Fixed (Stored in HLR) or Dynamic IP Address Allocation
8) APN (Access Point Name) Resolution
9) Capability to access packets at IP level and introduce delay, jitter, packet loss and packet corruption.



[Fig 12] GPRS Application Test Scenario



[Fig 13] GPRS Application Test Bed Architecture

Figure 12shows a typical application test scenario in which the signalling establishes the Temporary Block Flow (TBF) connection between the device and the simulated network followed by GPRS attach and PDP Context Activation at higher protocol levels. The application can then be triggered on the device as per the functionality to be tested (e.g. query or update) and finally the connection/session can be deactivated.

FUTURE TRENDS

The convergence of voice and data has paved way towards explosive growth inmobile telephony/internet. With the increase in the number of services provided by the vendors, the competition will become more stringent and the economic & technological constraints a force to reckon with. Now the focus is on applications as people are willing to pay for each new service created on this front. The solution lies in quicker development of inter-op solutions to deal with the increased number of challenges in testing domain.

- Consolidation (Like infrastructure sharing) Change in business model for the operators.

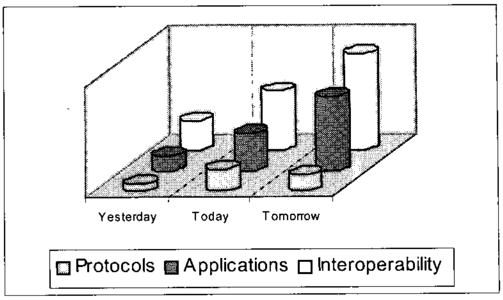
[Table 2] APPLICATION TEST COVERAGE

1. Functional Testing a. User to network information exchange (User initiated). b. User to user information exchange. c. Support for Radio Resource, Mobility and Connection Management Procedures between the MS (Mobile Station) and the network. d. Multiple users in a network. 2. Usability Testing a. Keeping the user in control b. Keeping the user informed 3. Server Side Testing a. Load testing at different throughput and QoS levels. 4. Interoperability Testing With different vendor devices and RF boxes. 5. Network Performance Testing a. Handling interruptions	1) Temporary loss of connectivity and rebouncing of connection. 2) User moving out of coverage area. 3) Class B terminal characteristics An incoming voice call during an active data session. 4) Handling of fatal interruptions (Suspend/Resume functionality) b. Dealing with latency c. The Effects of Packet Loss 1) Retransmissions at air interface. 2) Prioritization of packets. d. The Effects of varying bandwidth /traffic e. Robustness, Efficiency & Overhead Measurement & Optimization.

- GPRS should succeed before UMTS becomes a reality MMS could be the key driver here.
- Limited Mobility will be a convenient & inexpensive option in Asia with CDMA 1X
- Wireless LAN 802.11a to take off in 2003.
- Growth of new multimedia (Downloadable Games) and location based services.
- Integration of Java enabled PDAs with mobile networks enabling J2ME applications.
- Multi-mode and multi-band mobile devices.
- Quality rather than quantity based billing.

CONCLUSION

This paper discusses the various network simulation approaches used in verification and validation of wireless protocols and applications. The case studies demonstrate the test coverage and test efficiency achieved using the mentioned simulation architectures. As the number of protocols and networks consolidate and the applications multiply in the future, interoperability and backward compatibility would be the key testing challenge for the equipment manufacturers, content providers and the mobile operators.



[Fig 14] Test Challenges in the future

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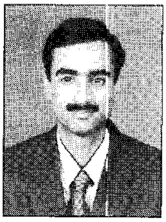
Biography



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From 1999 till date he has been working with HC L Technologies (Wireless and Embedded Solution s Group) in the area of protocol development and testing in GSM and GPRS domains. During this p eriod he has been instrumentalin designing generic test methodologies and reusable components for m obile protocols and network elements and has pres ented 3 Technical Papers in different international forums in this domain. His current assignment incl udes development of conformance test suites for E GPRS mobile stations.