Network Emulation Speeds Design of Wireless Devices/Applications

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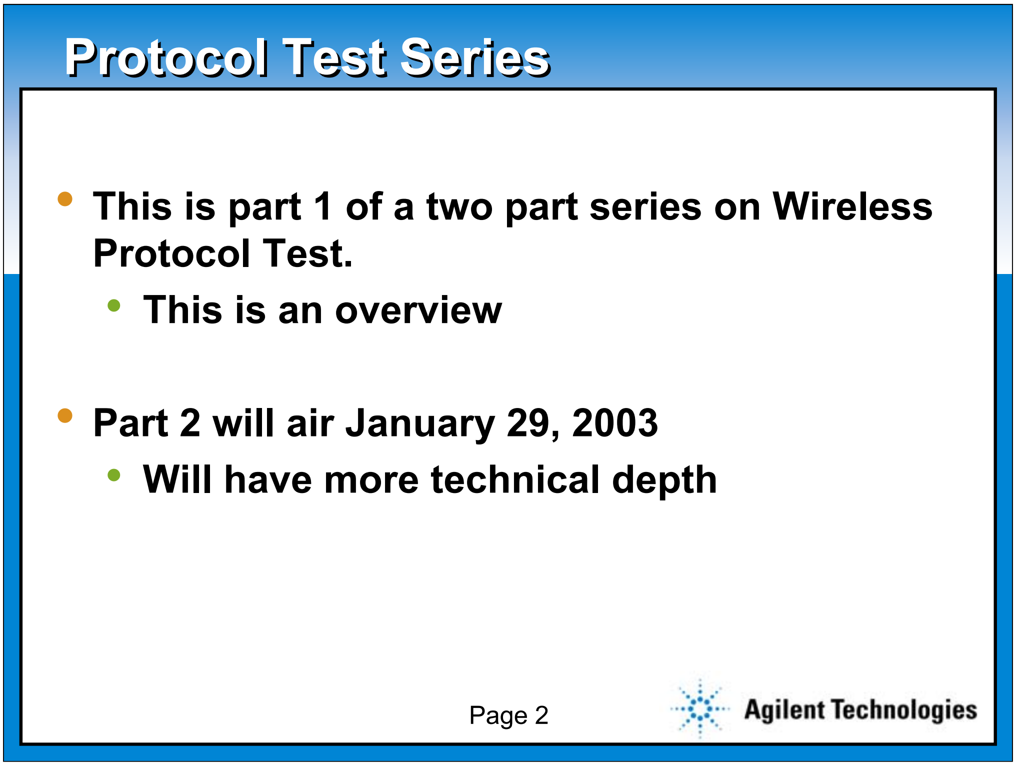
The Wireless Industry is presented with increases in complexity as it moves into the third generation. The addition of packet switched networks and connectivity to the Internet require vast amounts of interactive software, as well as features never seen in phones before, such as a browser.

This presentation will review elements of this complexity and present test models that will allow evaluation of the phone functions.



This is the first presentation in a two part series. The topics today are a general overview of the technologies and the test environment.

The second presentation will be on January 29, 2003. Two times will be available, at 6:00 AM and 9:00 AM Pacific Time Zone (US). It will go into greater depth of stacks and how layering is used to divide up the required tasks for data transmission at the expense of the added complexity of multi-processing as each layer is typically implemented as an independent function.

Agenda

- Market trends
- Challenge #1: Connection to the Internet
- Challenge #2: Emulate Real-World RF Environment
- Challenge #3: Monitor the Messages Over the Air
- Summary

So much of the industry needs are independent of the radio format; this presentation will treat them as a group. Specific examples will be given from either cdma2000 or GPRS.

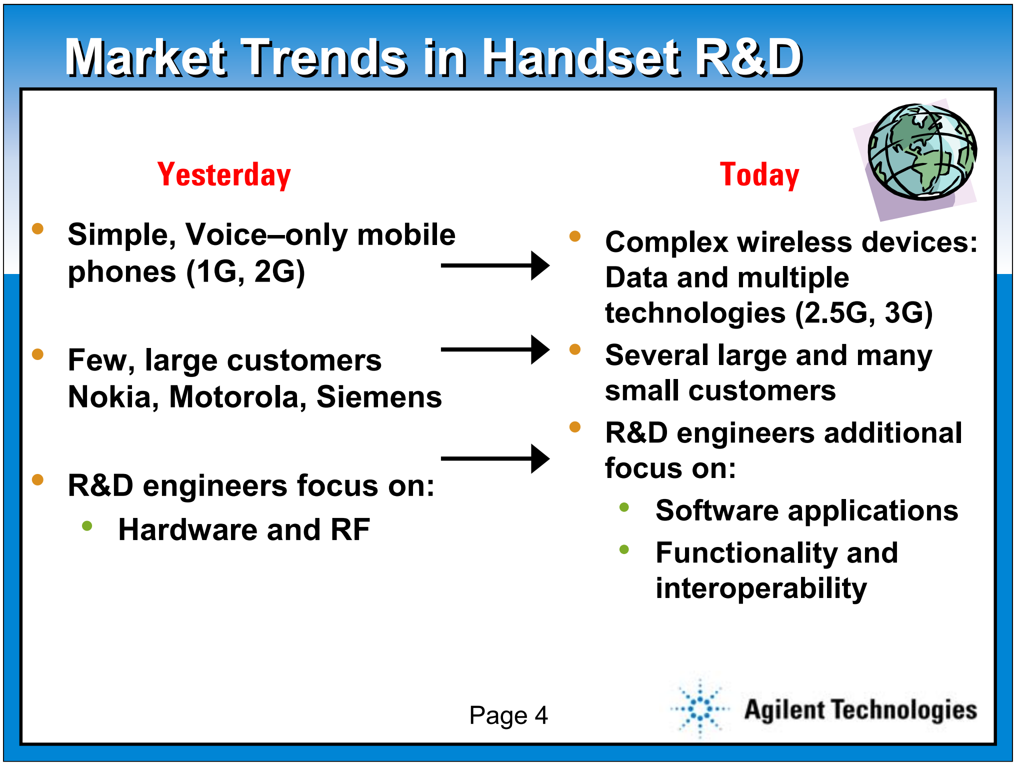
The presentations will first go into the driving forces in the wireless market that raise the importance of protocol analysis. This will be followed by the three key features supplied by our products:

•Connection to the Internet

•Simulation of real RF impairments to a data link

•The ability to monitor all messages over the air

There will also be a listing of our products.



The first generation of phones, analog, were voice only. Late in their development, some data capabilities were added, but these never served large markets. The second generation was digital, and includes GSM and IS-95 CDMA. Both of these started with voice, and added data services. The GSM data services are much more mature and deployed. Many of the operators of IS-95 systems decided to wait for cdma2000 before enabling data.

The third generation of cellular technologies (and what is called 2.5 G) are characterised by good data services, usually packet switched in addition to the original circuit switched data.

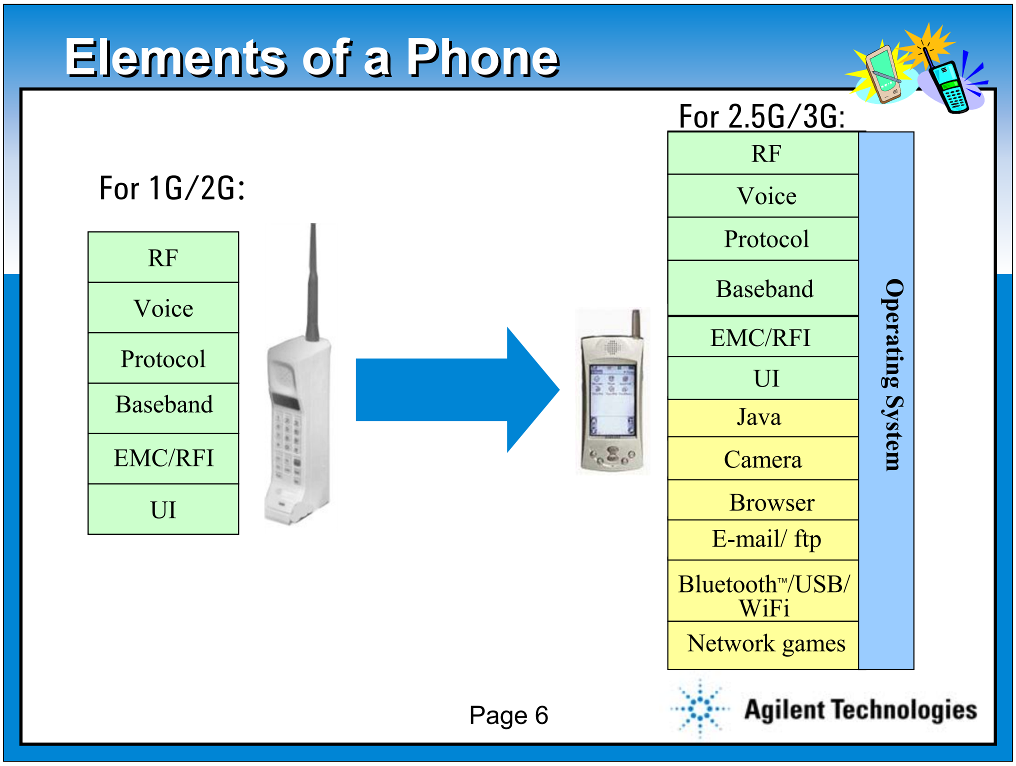
Packet switched data is much more complex in its messaging and control functions than earlier systems.

Many functions of the wireless devices are purchased from companies who provide custom IC, the chip set, and reference design. New phones also have a web browser.

The software content is much higher than ever before, and most of this impacts the air link messaging. The ability to monitor these messages with real data is the focus of our products.

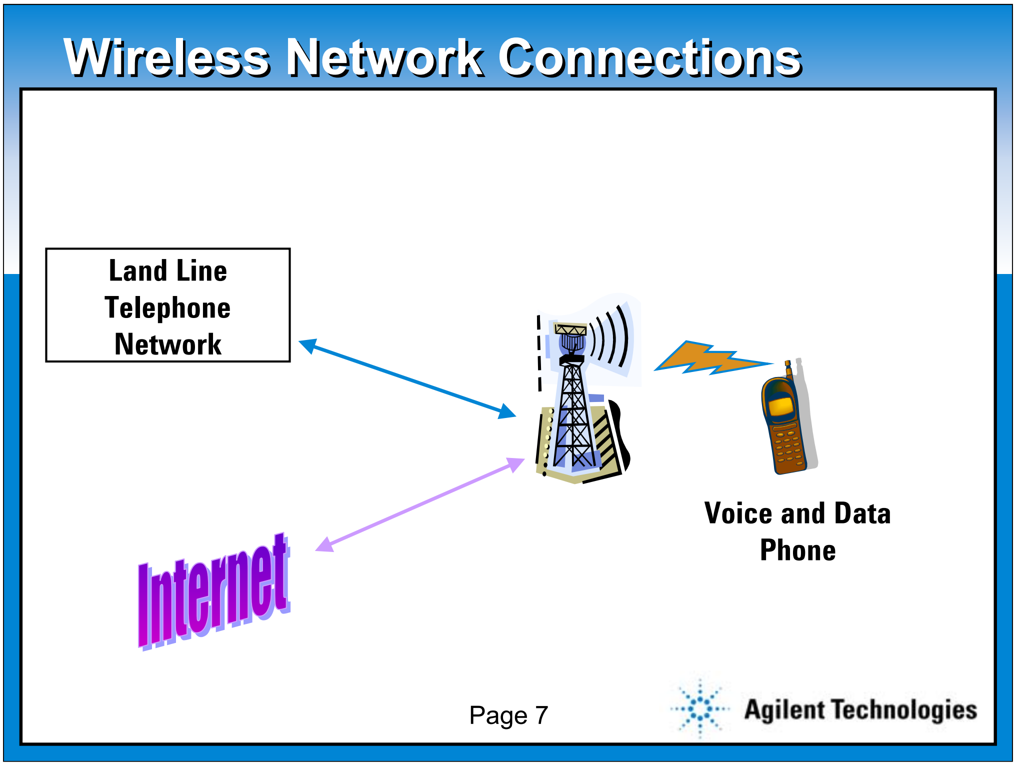
Pictures with automatic email. Stock prices and purchase. Airline times of arrival and departure with gate information. Weather reports. Traffic reports. Interactive games. Distinctive ring tones for the phone. PDA functions. Email. Internet access. Support of external computer with modem functions.

Where will it end? That is actually the wrong question. We have reached the stage were we are no longer limited by exactly the feature set originally installed in the phone. Instead, we now can download new features and operating programs that add new features.



One segmentation of device functions are shown on the left, in green. These same functions still exist in newer designs, but have been augmented by additional features.

One area that is common, Protocol, has been significantly enlarged in the newer generation of phones.



Originally, there was only the phone network available for handling wireless calls. Any data application was carried on that network along with the voice information.

Starting with GPRS, a second connection path was added that allows data transfer to and from the Internet. cdma2000 has similar functions, now. While many of the complexity of this growth occurred in the land switching systems, the link to the phone has control and messaging functions for both set of services.

Problems Facing R&D Engineers

R&D becoming even more complex and challenging!

- **Multiple air interface technologies (2G, 2.5G, 3G, Bluetooth™, WLAN)**
  - **2.5G and 3G signaling protocols are 4-10x as complex as 2G**
- **Device components increasingly complex**
  - **Major issues with integration of the software components within the phone**
- **Lots of incremental integration and regression testing needed**
- **Exponential increase in network and device interoperations**
  - **Major issues with interoperability of data information**
  - **Increasingly difficult to verify if a device works properly in various networks**

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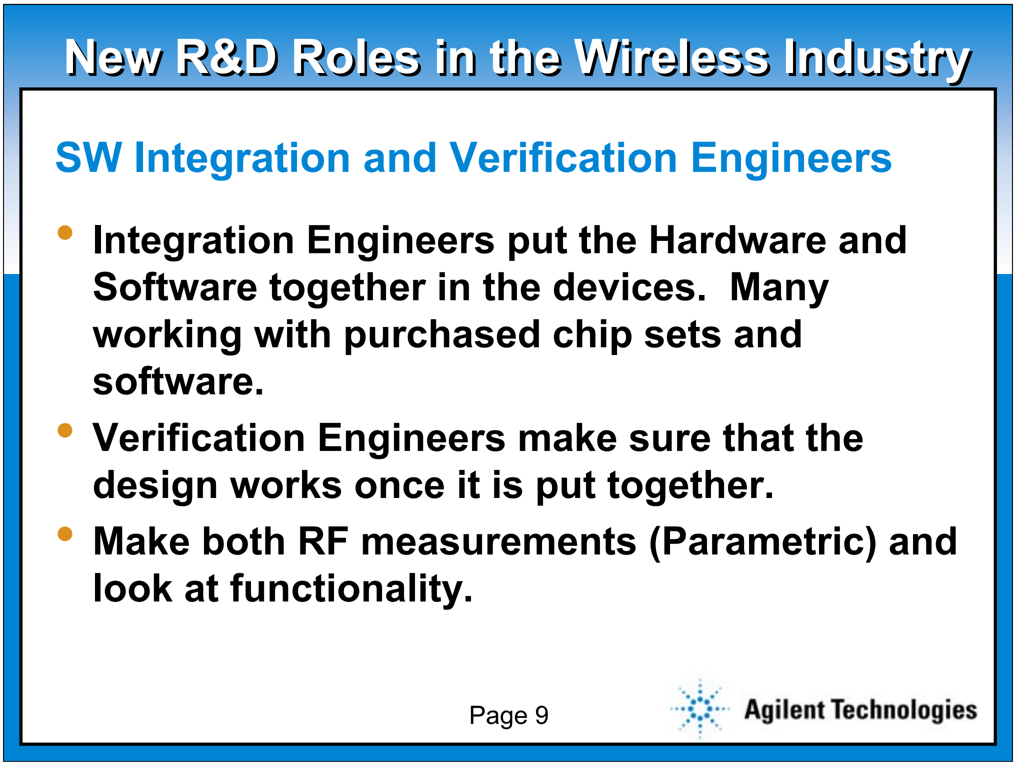
R&D now has functions that didn't exist a few years ago. Many applications are being designed that are independent of the delivery mechanism. This requires clear segmentation of applications that may use Internet data from the data flow control functions that are unique to each format.

Often, elements of the software are purchased and integrated, rather than being design in-house. This changes much of the R&D function from design to integration. A separate validation step is critical to the qualification process of a design. Proper instrumentation can greatly improve the efficiency of both integration and verification.



Engineers are now often asked to integrate purchased software, rather than develop it internally. Bug fixing is then a combination of modifications to the purchased code, and bug reports back to the originating company. Verification is similar, but without the bug fixing. Both functions can benefit from better diagnostic and documentation tools.

New Roles in the Wireless Industry

SW Development Engineers

- Develop and integrate software as part of the device
  - Protocol and the User Interface (UI)
  - Wireless Application Developer
- Develop and integrate application software to go into devices
  - Operating system, Email, Browsers, Camera, Games and Interfaces to other devices
  - Embedded App. Developer
- Need to evaluate functionality.
- Need to see that the S/W knew when it lost data and handled it.
- Need the control of timing to model the real world

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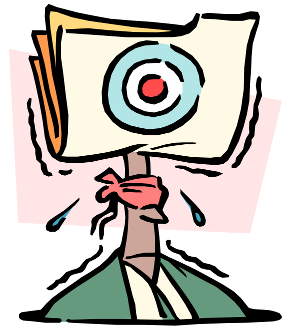
Many times, Agilent may not currently have direct contact with the engineers doing integration or verification. This should change now with our focus beyond RF into the Protocol and Application space.

Many of these engineers do not need the full RF measurement capabilities of our full-featured products, and the Protocol Analysis products may be a better fit.

Bottom Line

- New Problems
- New Solutions



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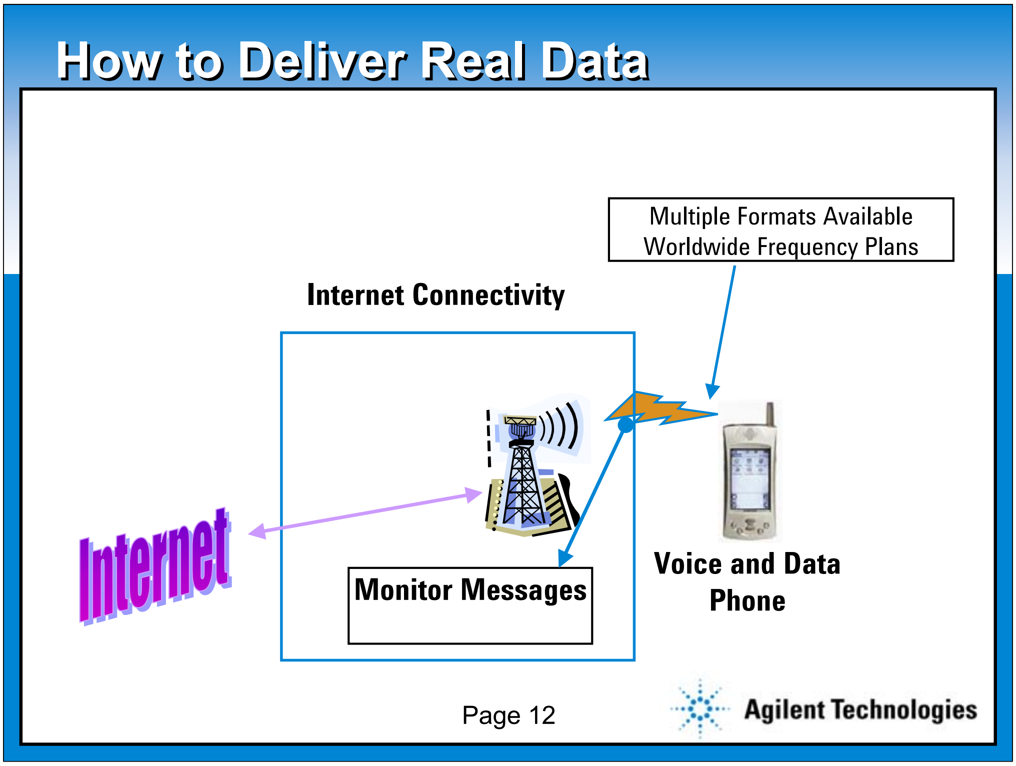
The added complexity has caused new problems in validation. In order to be more efficient in this industry, better tools are needed, as well.



The wireless industry has multiple formats. The Internet is shared by all, however. What is needed is a transducer that can connect to the Internet with a network connection, and to the phone with a cabled connection that carries the properly formed RF signal of the format being tested. In the middle, a monitor of the messages needs customization for each format, as well.

The three major features to enhance the test environment:

1. Connection to the Internet
2. Emulate Real-World RF Environment
3. Monitor the Messages Over-the-Air

These will be further discussed in the following slides.

Challenge #1: Connection to the Internet

- Need to Confirm Functionality:
  - Web Browsing
  - Animations (Java)
  - Graphics
  - Data Rate/Flow control
  - Screen sizing

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The Internet can provide a wealth of applications, too numerous to be able to support from a stand-alone piece of equipment. Examples of this include web browsing, graphical interface, and FTP.

Often a phone development team is working on a family of devices, which may have different characteristics, in particular, the screen size and type. Some may be monochrome, while others may be color. The range of options needs testing.

How it's Done Today

- Use real networks
  - Little control of parameters
  - Expensive
- Network simulators/conformance test systems
  - Very expensive
  - Very complex to use
  - Too simplistic, only simulate portions of the network
- Home-built systems
  - Expensive and difficult to operate and support
  - May not offer all the needed flexibility
- One-box test sets offer limited capability

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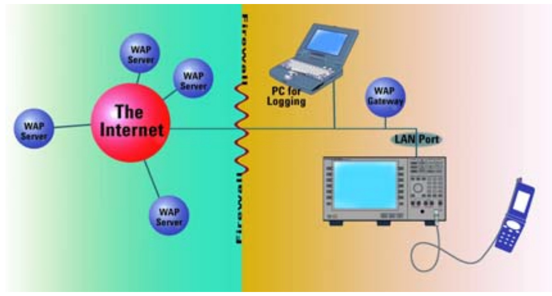
One way of doing it today is by visiting a site that has active service. That is possible for GPRS and cdma2000, but not so for W-CDMA. It may require special arrangements with a service provider to allow access to a device that doesn't have approval for service. In addition, there is not flexibility to modify network settings such as coding structure, rate, target error rate. Feedback systems active in real networks may prevent testing to the limits of performance.

Conformance test systems can be used to exercise the air link protocols, but don't allow connection to the Internet at speed. Typically, these are very expensive.

Home built systems are expensive to develop and support. The flexibility may not be available to emulate all the desired types of applications.

Put the Network on Your Bench



- **Access multiple technologies/networks in your work area in one instrument.**
- **Affordable**
- **Easy to use**
- **High rate data connection**

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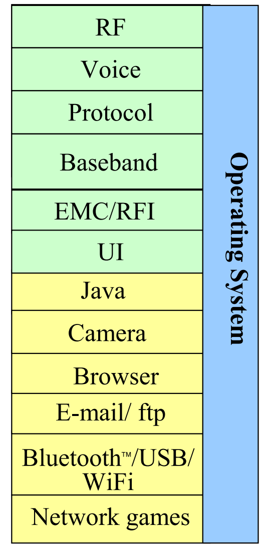
An improved solution is to put wireless access on your bench. The test products become the transducer between the Internet and the wireless device being developed or tested. Full message instrumentation is available for the link.

Test Focus

- **Browser Functions**
- **Photography**
- **Application Testing**
  - **Speed**
  - **Latency**
- **Auxiliary Device Interfaces**
  - **USB**
  - **Bluetooth™**
- **Resource Allocation for Packet Connection**
- **Packet Data Flow Control**



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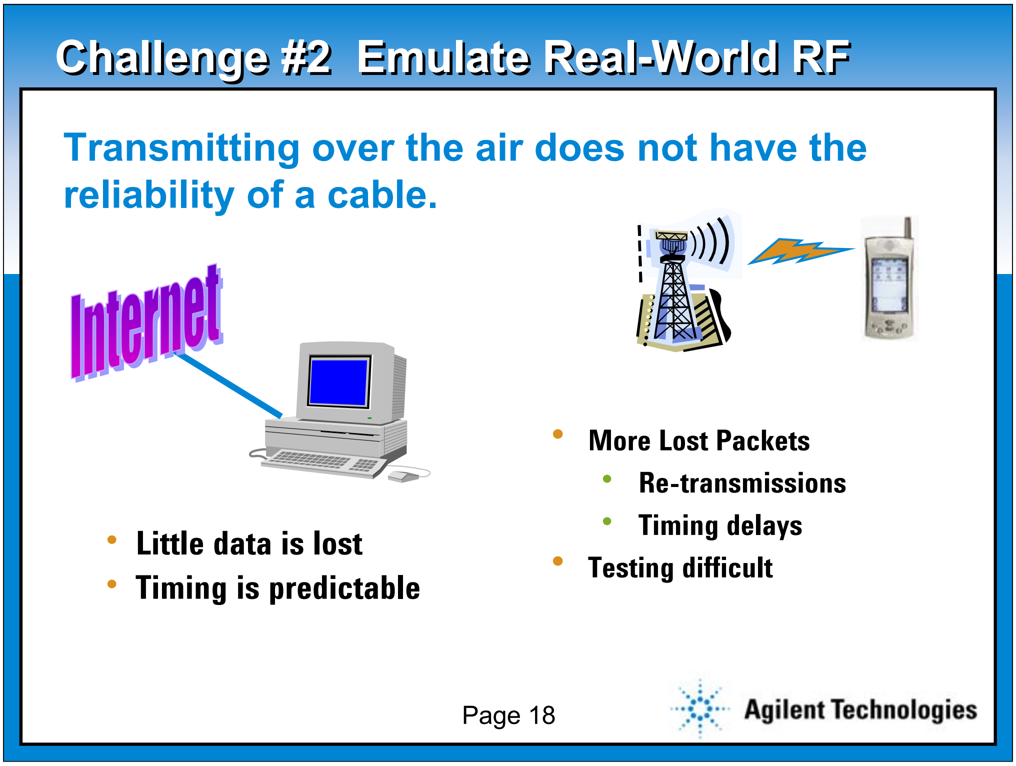
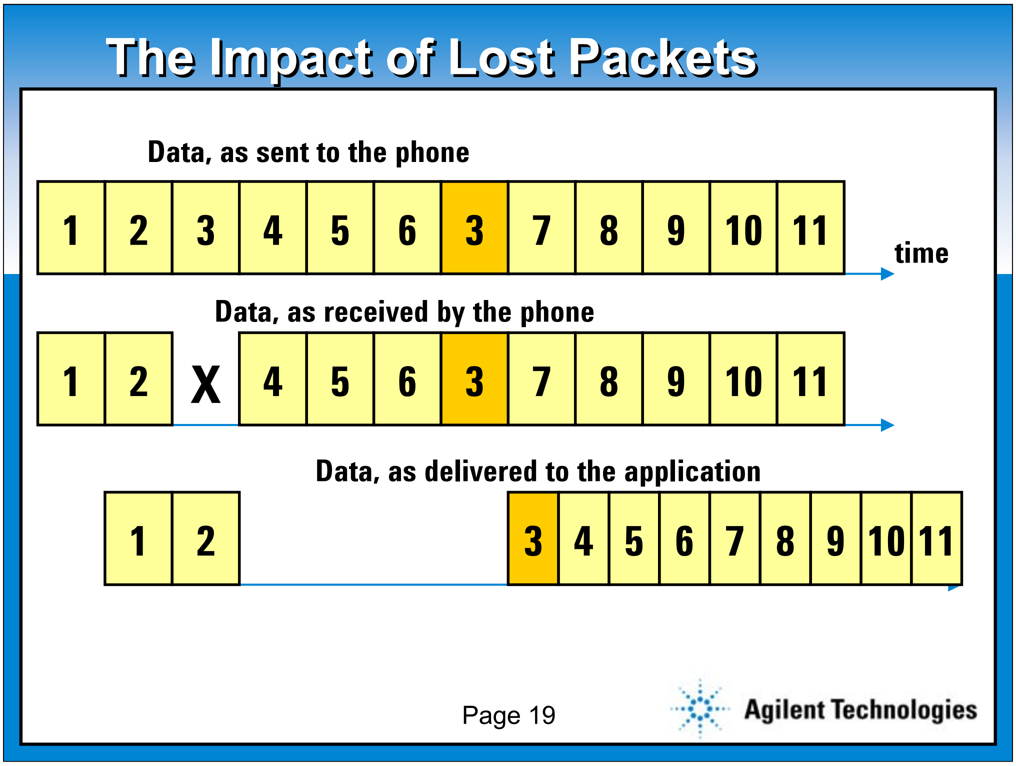
Numerous applications exist on the Web. What is the impact of different channels speeds on interactive gaming? Does the interface to an external computer work? How fast can my device work under the best of conditions?

At some time, each of these functions need to be tested. In the case of web-based applications, the content of the traffic may drive the actions of the phone, rather than the messages themselves.



The environment of a packet connection that uses a radio link is very different than one that is wired. While the protocol for each system allow for lost packets and the control functions that result in a re-transmission, the occurrence on the wired Internet is very low, while the link over-the-air typically targets an operating point near 1% lost packets.

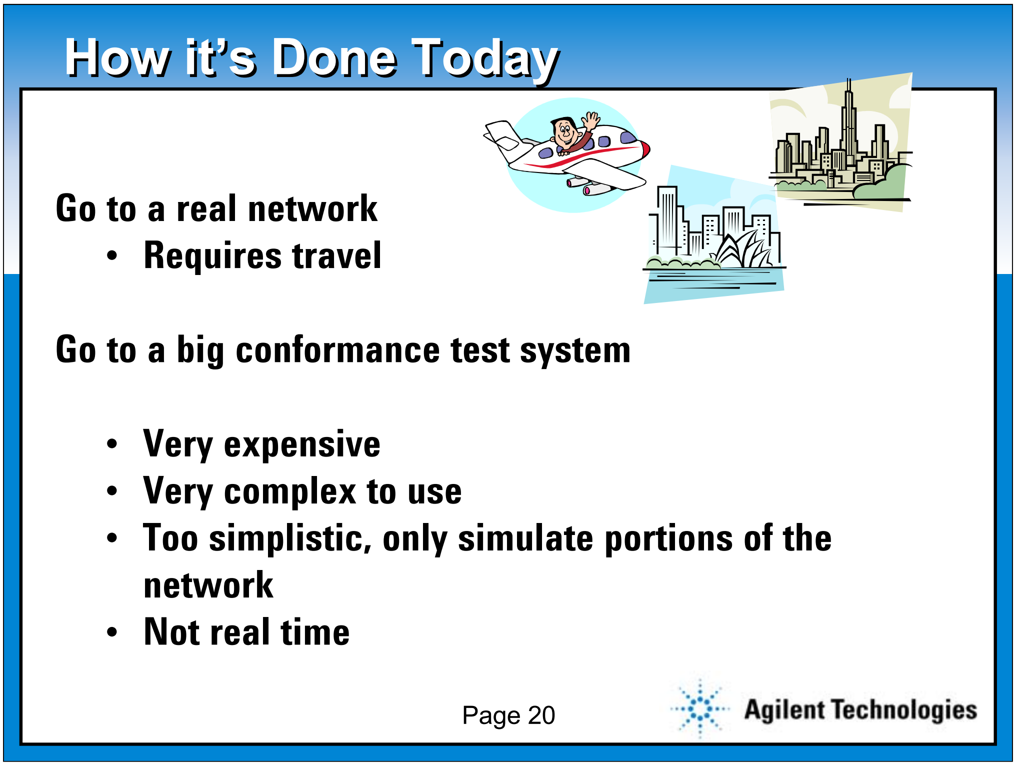
This is very difficult to simulate with wired connections, and is better emulated with real hardware and a link that has been adjusted to yield errors at the desired rate.



This picture shows the effect of a lost packet. Packet 3 is lost in its transmission. Not shown are the messages between the phone to the network asking for a re-transmission. The network is required to put higher priority on re-transmission of a lost packet than on the transmission of a new packet, so the lost packet is sent over the air quickly.

The network has memory requirements to keep a copy of each transmitted packet long enough to be sure a re-transmission won't be requested. The phone has memory requirements to buffer the packets received after the lost one, and build the data stream correctly after the lost packet is received correctly. As you can see here, the application does not get a steady flow of data, but may have gaps with no data at all.

The messages, priorities, and rules for memory management in both the network and the phone are all part of the standard, so the test environment must be uniquely modified for each standard.



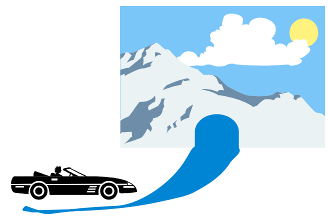
Most people simulate the data connection with cables and bypass the RF functions of the phone. The data connectivity is provided without the impairments that are common in the RF environment.

Again, going to a real network can be of use, but the feedback in real systems may limit the range of testing. Also, there is limited or no control over the available coding structures.

Using a conformance test system will provide the desired RF environment, but not the high speed Internet connection. As I have said before, these systems are big, expensive, and require trained operators.

The Better Solution

- Provide a controlled environment to test connectivity to a network without the need to use a live RF network.
- Control of :
  - RF power
  - Data coding structure
  - Data rate
  - Number of time slots
- Can emulate network timing real-time



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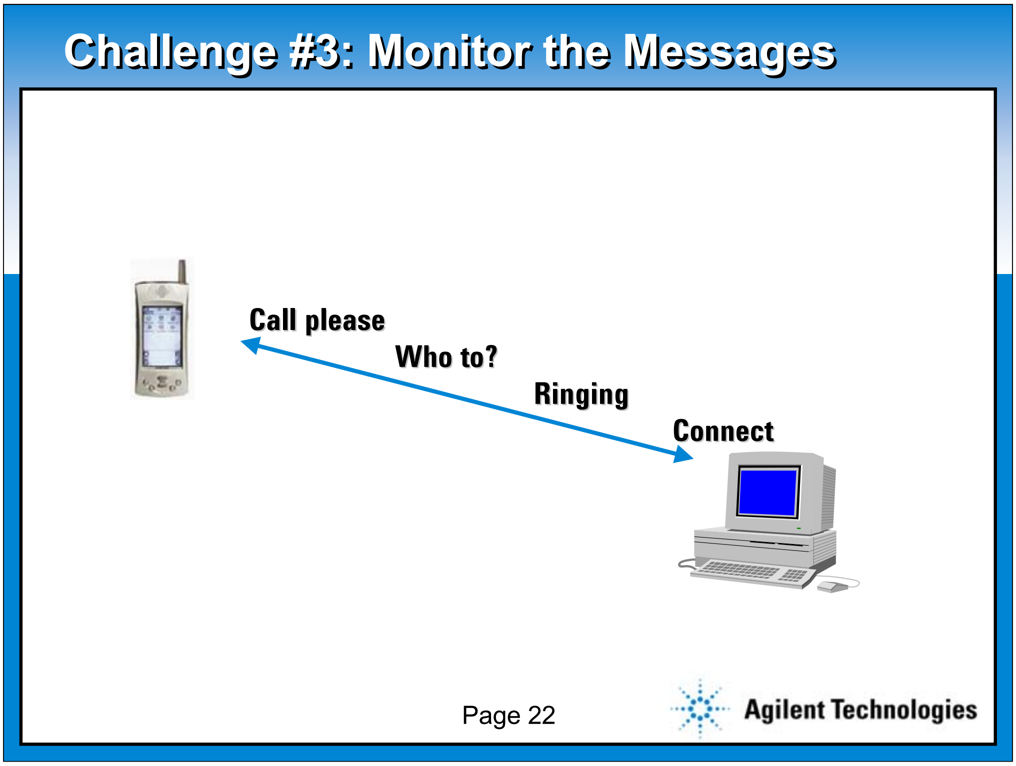
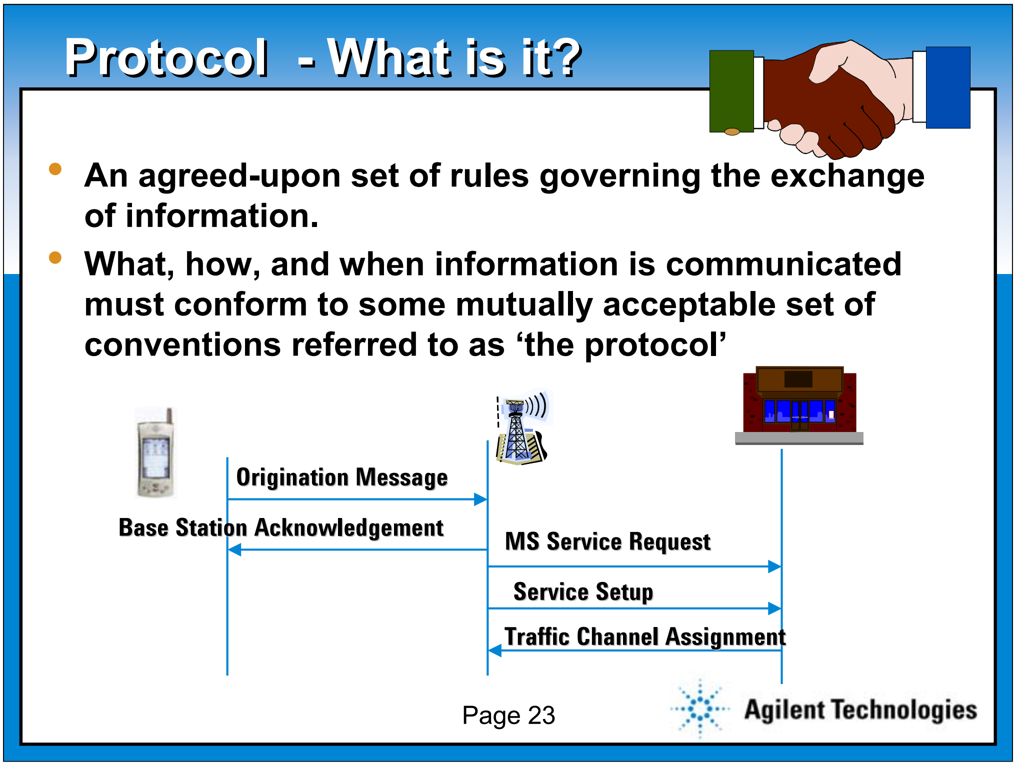
Our solutions provide a network on a bench. It's a matter of setting several IP addresses correctly. Our products provide easy control of the coding structure and associated data rate, the RF power level, added noise in CDMA systems, and the ability to monitor the messages.



The messages transmitted over the air are executed by real-time software applications in both the phone and the network. Every bit has meaning, and a wrong bit can easily be inconsistent with the desired action. Often, the result of this is an immediate drop of the RF link, with no warning. Troubleshooting such a situation is very difficult. The ideal solution is to monitor all messages both in the phone and in the network equipment. These can be compared, bit by bit, to find errors. Monitoring the messages only in the phone will often not provide enough information to determine where an error may be.

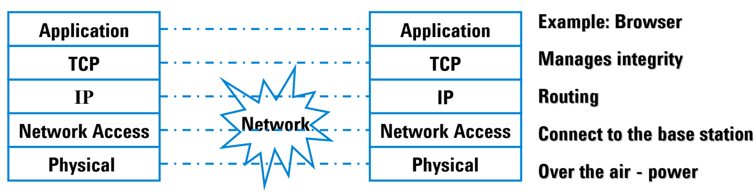


In its simplest form, Protocols are a list of rules on what can be said, and when between network entities. The phone can only talk to a base station, but the base station has two underlying networks, the circuit switched phone network, and the packet switched data network, commonly called the Internet.

Certain message sequences will change the state of a phone. For instance, a phone may start in Idle state, and progress to a Voice state by sending an origination, and getting a channel assignment.

Layering

- Communications functions are partitioned into layers. Each layer performs a subset of functions.
  - Layers provide services to upper layers without those layers being concerned with the implementation details.
  - Layers use the services provided by the lower layers to send their information
  - Peers communicate using a protocol
  - A collection of protocols, one or more per layer, is a protocol stack.



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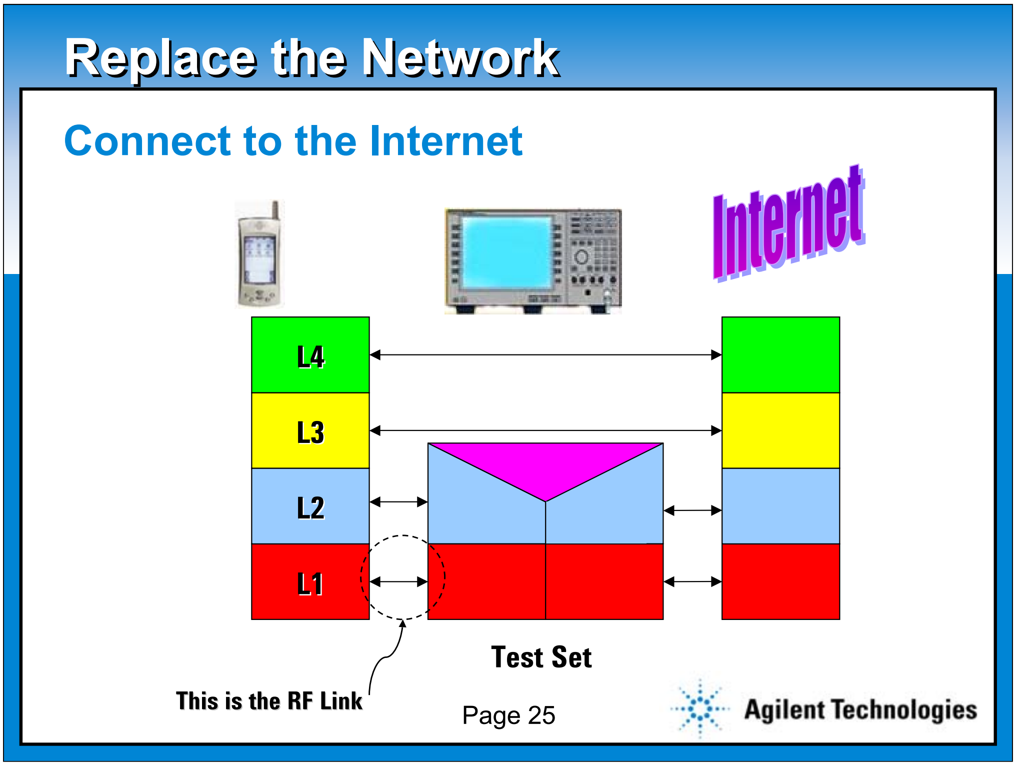
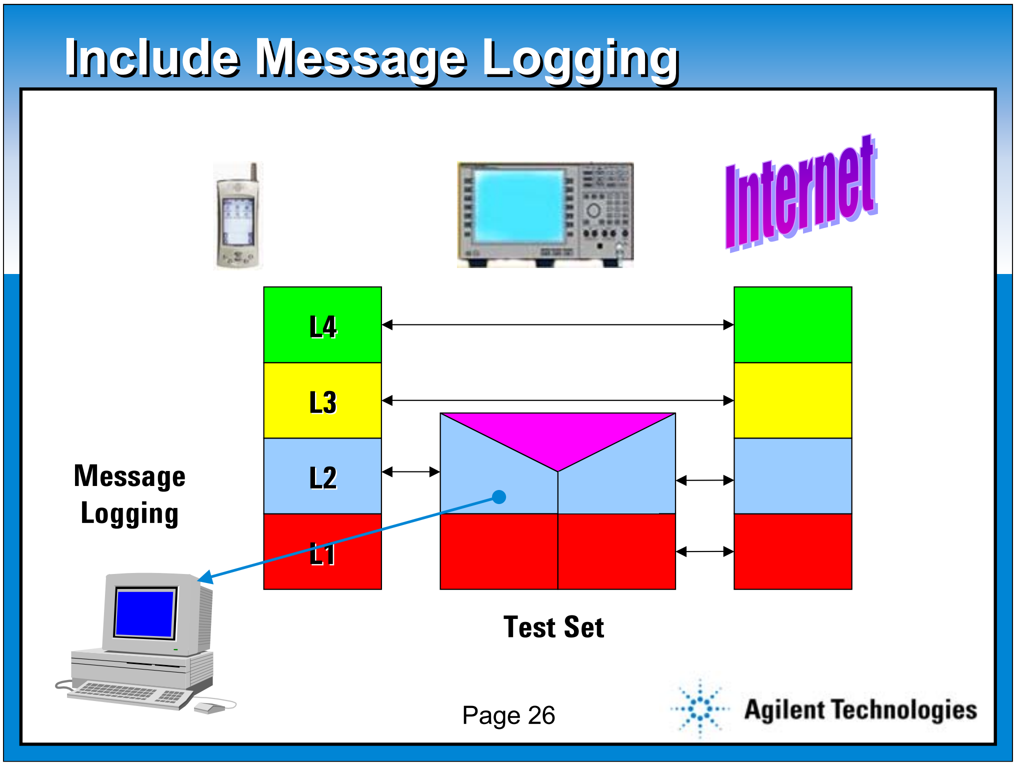
The implementation of Protocols is done in a layered system. These are based on the OSI 7 layer model, with some modifications specific to the wireless systems. While the actual connection only exists at the physical layer via the RF link, there is a virtual connection between each layer and its counterpart. These are called peers, and the set of rules for a given peer layer is often a separate standard in itself. The implementation of these layers in a phone may often be done by different people, and in relative isolation from each other. It is important that the analysis of the messages over the RF link be tied to its layer. It is also important that message logging can be enabled or disabled for each layer.



This shows how different layers of a stack can come form different devices. The stack on the left represents the phone, the second the combination of the base station, the network, and a mapping function needed to get the data to the Internet. The stack on the right is the internet. The phone has physical and data flow connections with its own cell, but the next layer up, IP, is transferred from the Internet. It has been passed through the intermediate pathways. In a real network, there are several switching or routing steps between a phone and the Internet.

It should be noted that the black line with two arrows at the bottom left represents the RF link in both directions. We have spent a major part of our careers measuring power, noise, harmonics, sensitivity, spectral purity of this link. Now, if you add some intelligence in the phone at layer 2, it becomes a modem.



Along with the actual connection to the Internet, there is the ability to log messages carried in both directions on the RF link.

How is Messaging Analyzed Now?

- **Protocol tools designed for wireline networks provide some logging functionality, but no analysis**
- **Home-built loggers in the phone but not in the base station**
- **Logic analyzers verify timing and contents in binary**
- **Some network emulators have protocol logging, analysis is manual**

Most phones have the ability to monitor the messages sent and received by them. At first glance, this would seem to be sufficient, as this is all the messages. However, when something goes wrong, it is often useful to see the messages and their content at the base station end.

Logic analyzers can often retrieve the bits, but decoding the message contents by hand is laborious and error-prone.

Other Test Issues:

- Regression testing is important
  - Devices are designed differently – many revisions from one platform
  - Software upgrades are a way of life – constant testing required
- RF parametric measurements synchronized with protocol analysis
- And etc……

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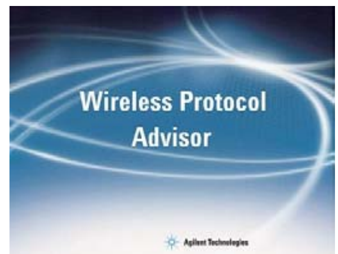
Often a software package for a phone is written as a superset of all available features. Internal "switches" are set to enable or disable each feature. Not all the features are possible at the same time, or there may be several options on one feature. Often, qualification is performed on one configuration, while a final product will have different switch settings. Some form of validation is important to test the operation of this design. Typically this would be in some form of regression testing, where a known suite of tests is performed on the phone using a standardized test setup.

Tailored Protocol Analysis

- **In-depth logging and analysis specifically for multiple-format air interfaces.**
- **Real-time, high-performance logging**
  - **Flexible filtering and triggering**
  - **Post capture viewing**
  - **Bi-directional messages**



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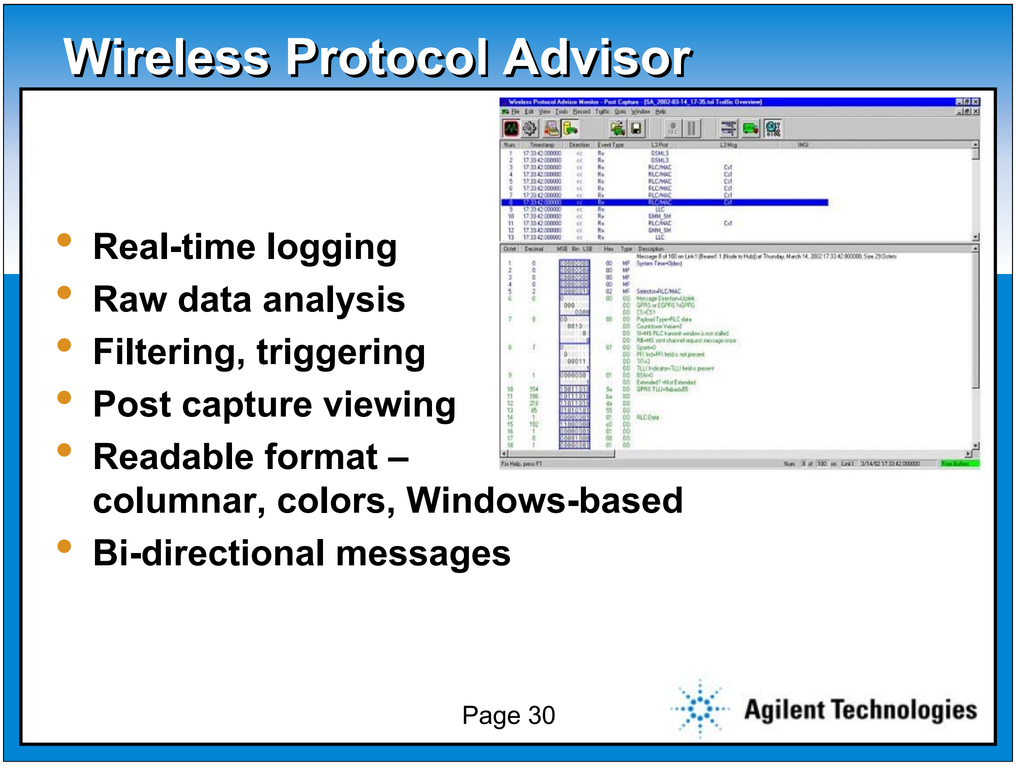
The Agilent Protocol Analysis is performed in a software package called the Wireless Protocol Advisor (WPA). This is a program that runs on a PC and connects to our base station emulators with a network connection. WPA is included with each Lab application and Protocol Application.

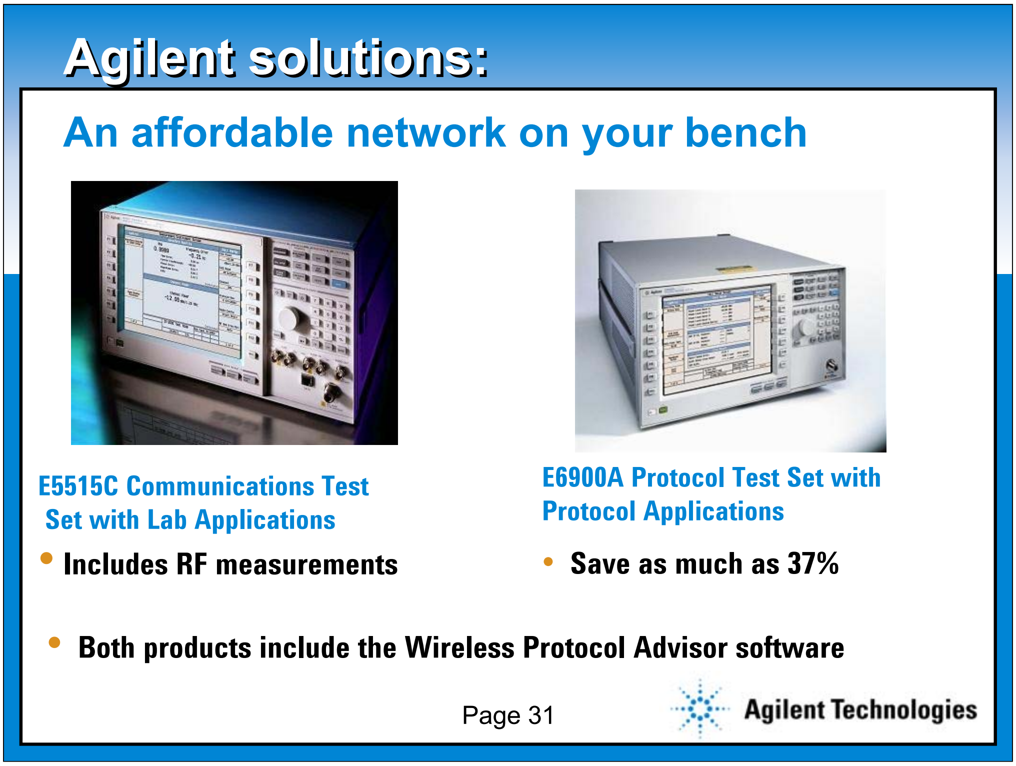
WPA has the capability to select probe locations, filter certain types of messages, and trigger on specific events.

Message sequences and message contents can be saved for later analysis or for documentation purposes.



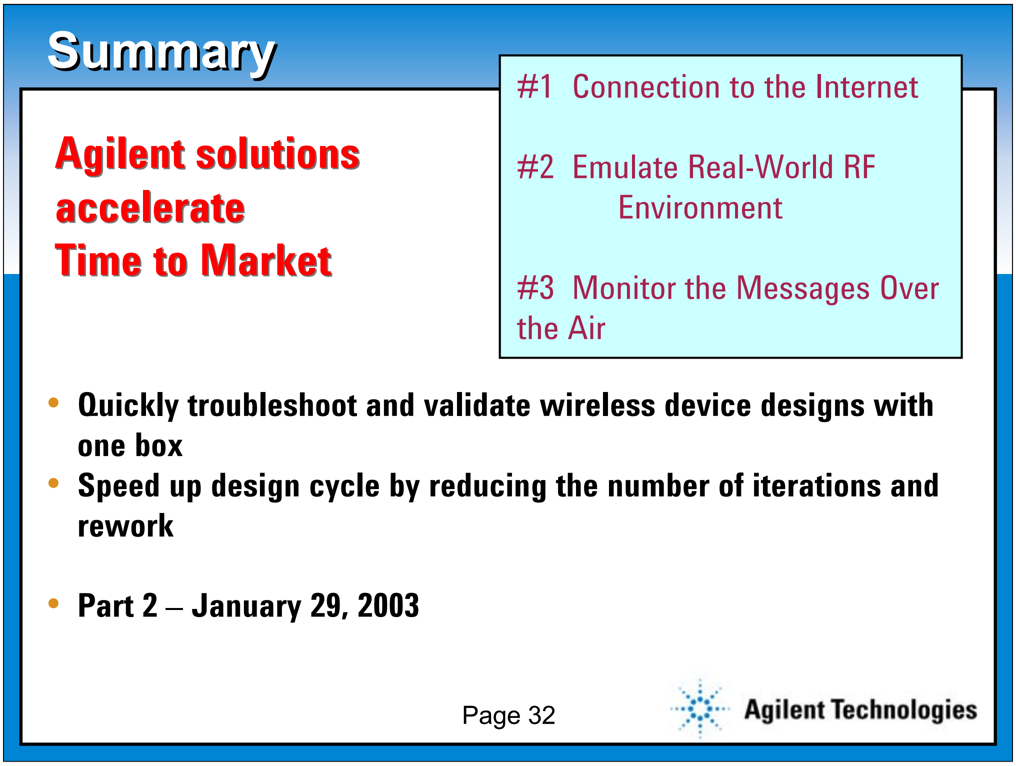
Here is an example of a protocol log on WPA. The upper window is the sequence of messages, while the lower window provides the details of the message in blue in the upper window.

There is a breakdown in hex, decimal, and binary of the message, and the bit packing can be shown. The meaning of each field is shown green on the right.



The E5515C is the industry standard for speed, accuracy, multiple formats, and versatility. We developed Test Applications (TA), targeted at manufacturing, and Lab Applications (LA), where the feature set of the TA is enhanced with improved RF test capabilities and with Internet data connection and Protocol Analysis.

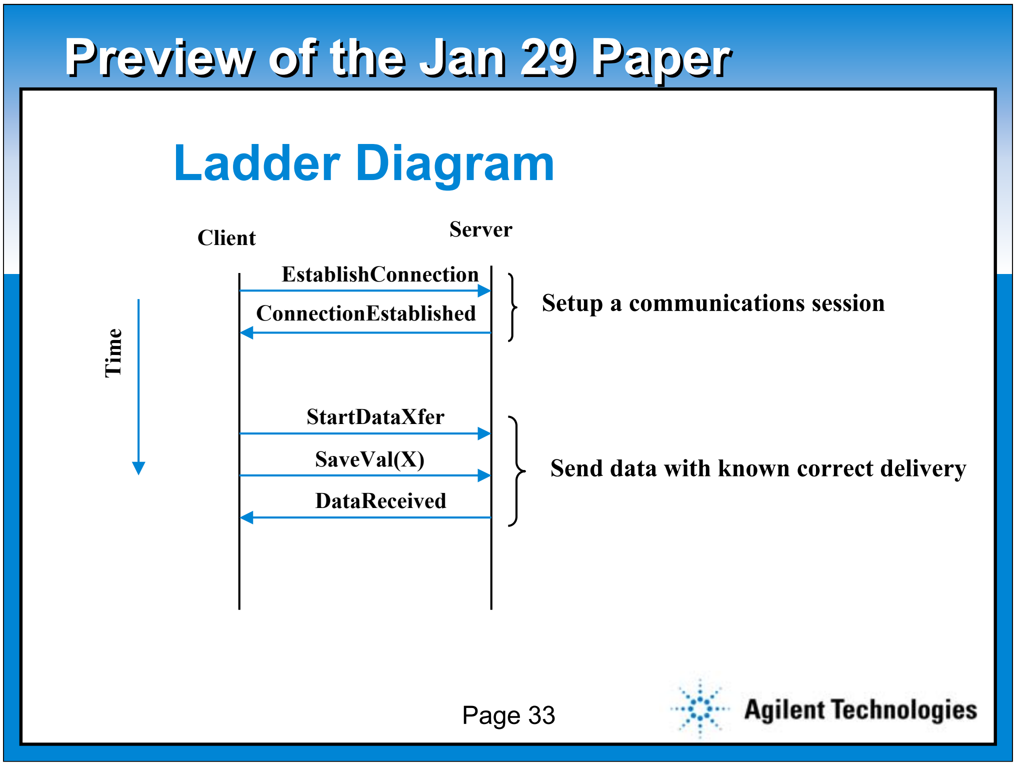
Many customers really only want the enhancements in the Protocol area, so the E6900A was developed. This takes the RF measurement capabilities and calibration out of the E5515C to provide a protocol analysis solution for a lower price. The Internet connection and protocol analysis functions from the LA are now available in a Protocol Application (PA).



The Network on a Bench approach provides major features not previously available. It provides more flexibility than use of real networks, without the trouble of finding one to use.

Real Internet connections can provide stimulus for Browser functions, with realistic impairments.

The messages can be recorded from the air link.



Let's consider the earlier example, but add a few more elements to the protocol. First, I want to add a request for connection, with connection granted. Then I want to add a flag before transfer of data, and I want an acknowledgement when the data is received.

A ladder diagram for this is really quite simple.

ISO-OSI 7 Layer Model

International Standards Organization - Open Systems Interconnection (ISO-OSI) 7 Layer Model		
Layer	**Function**	**Typical Protocol**
Application	Specialized network functions such as file transfer, virtual terminal, electronic mail, and file servers.	
Presentation	Data formatting and character code conversion and data encryption.	
Session	Negotiation and establishment of a connection with another node.	
Transport	Provision for reliable end-to-end delivery of data.	TCP
Network	Routing of packets of information across multiple networks.	IP
Data Link	Transfer of addressable units of information, frames, and error checking.	RLC
Physical	Transmission of binary data over a communications network.	GPRS Physical

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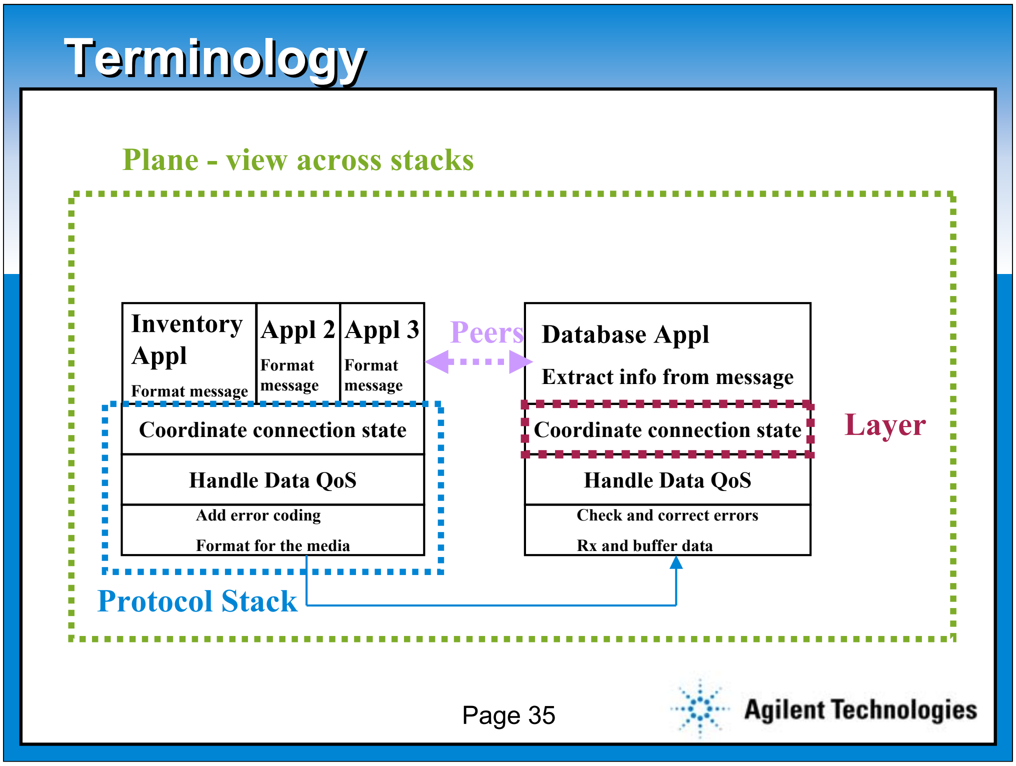
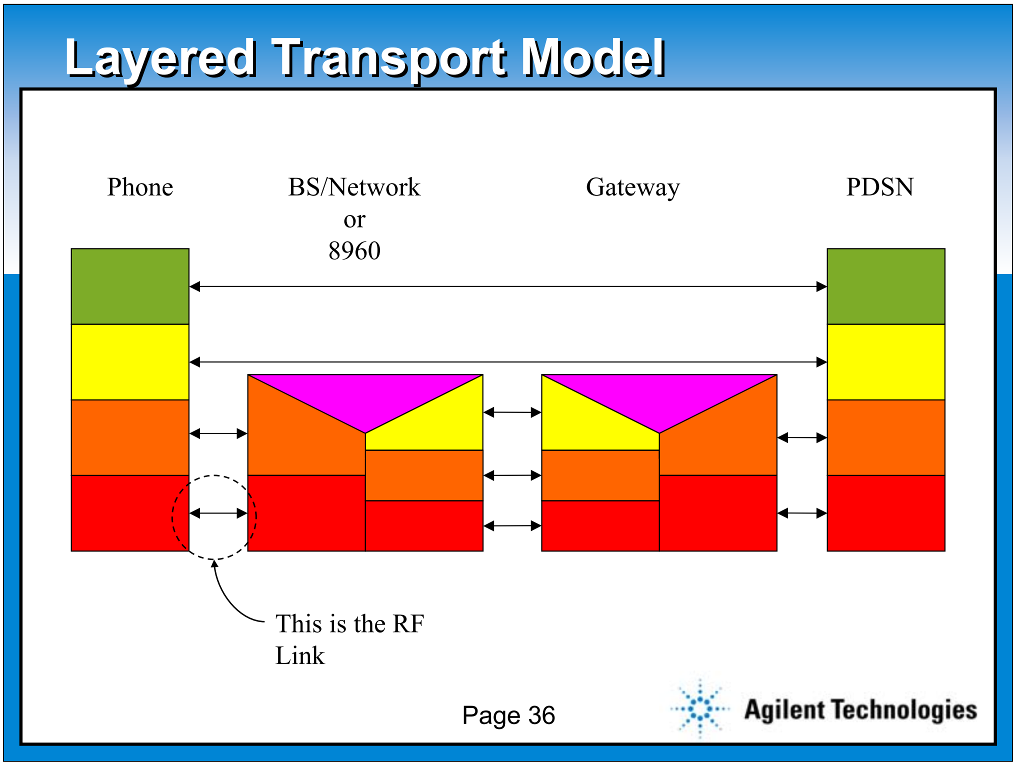
All of this layering is based on work done by the International Standards Organization in their Open Systems Interconnection 7 layer model. The physical link of GPRS does not have a unique name, it includes the coding, which can be to four different levels of error protection and the modulation. Layer 2 is comprised by the Radio Link Control (RLC) and another sub layer called the Medium Access Control (MAC). On the transmit side, these break apart a large data file into smaller packets suitable for transmission, and number each. On the Receive side, the RLC/MAC rebuilds the original large block. The higher layers are the same Internet Protocols we normally use in wired applications.

Most wireless systems violate the ISO-OSI model frequently. An example is the addition of a CRC on each data block. This is typically implemented in hardware; comprised of a shift register and a few XOR gates. As this is physical in nature, this is done as part of the physical layer, even though is specifically is a layer 2 operation in the model.



A view like this is called the plane view. It looks down on the layered structure, and shows the stack on each side. The stack is the collection of layers, and a layer is a single entity with specific role in the overall process.

Each layer in has two roles: transport messages to and from higher layers, and to exchange messages with its peer. A peer is always at the same layer on the opposite side of the link. So, while the inventory application is transported down by each of the lower layers, transported by wire to the bottom of the alternate stack, it rises up the stack and ends at the same layer. The QoS layer cannot communicate with any layer on the other side other than the OoS layer.

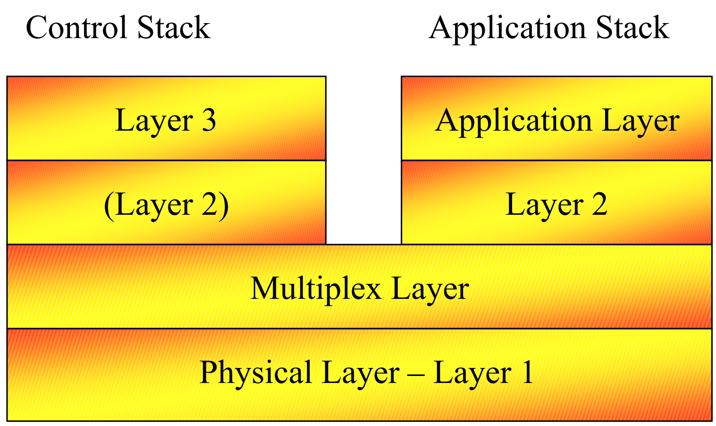


This shows how different layers of a stack can come from different devices. The stack on the left represents the phone, the second the combination of the base station, the network, and a mapping function needed to get the data to the Internet. The third stack, the gateway, is not used for wired connections, it will be discussed later. The stack on the right is the internet. The phone has physical and data flow connections with its own cell, but the next layer up, IP, is transferred from the internet. It has been passed through each of the intermediate pathways.

The gateway is necessary to allow WAP web pages to be adjusted for a specific phone. At my latest count, there were 17 different screen sizes available for wireless web applications. The gateway would map generic data onto each of these screens.

It should be noted that the black line with two arrows at the bottom left represents the RF link in both directions. We have spent a major part of our careers measuring power, noise, harmonics, sensitivity, spectral purity of this link. Now, if you add some smarts at layer 2, it is just a modem.

Generic Wireless Protocol Stack

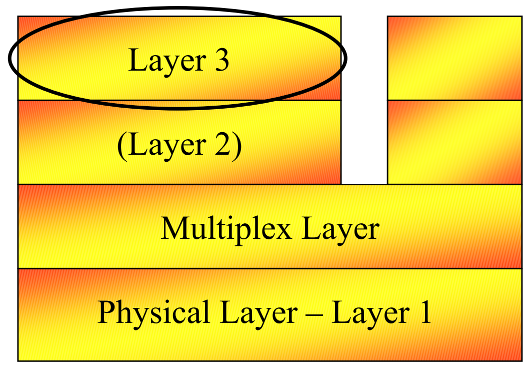


Interesting Layers – Control Stack

Layer 3 of the Control Stack

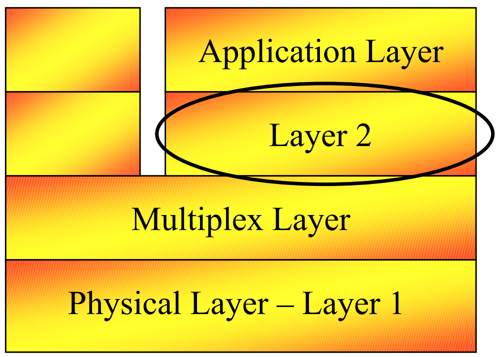
- Phone Control
- SMS
- Authentication
- Call Setup/Caller ID

Control Stack



Interesting Layers – Application Stack

Application Stack

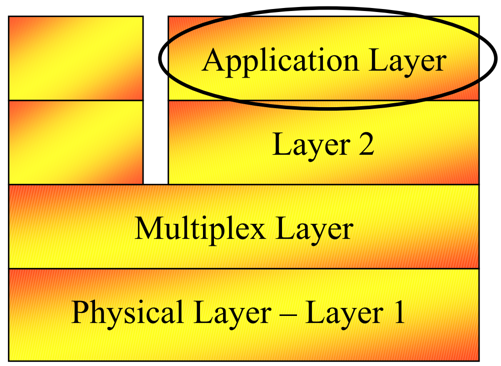


Layer 2 of the Application Stack

Controls the Data Transfer

Interesting Layers – Application Stack

Application Stack



Application Layer

Web Browser
MP3
Interactive Games

The content is more interesting than the messages

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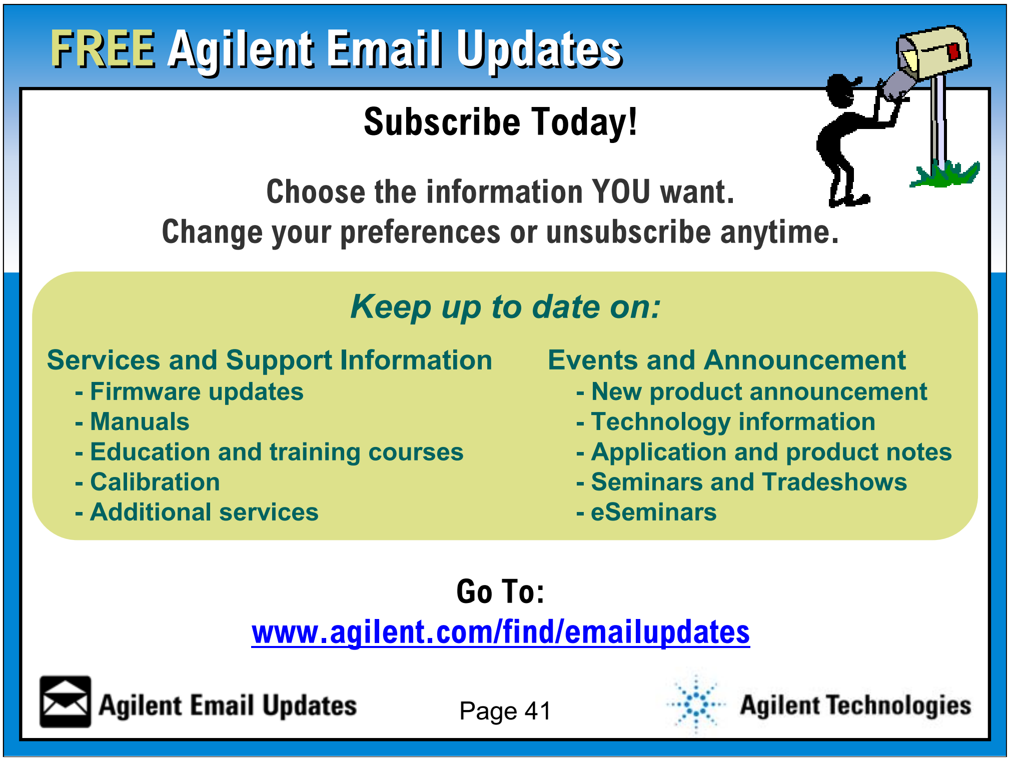

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