RTT TECHNOLOGY TOPIC
March 2004

Handset Hardware Testing

This Month's Hot Topic focuses on the conformance testing of 3G phones, specifically, the conformance and performance testing of handset hardware. The next three Hot Topics (April/May/June) will look at handset software, network hardware and network software testing. The four Hot Topics taken together will provide an overview of some of the practical issues still to be resolved in third generation handset and network testing.

The role of test and measurement has always been fundamental in two-way and cellular radio design. Wireless devices cannot co-exist in comfort without adhering to relatively precise 'radio rules of engagement'. Even simple FM and AM two-way radio transmitters have to work within closely specified radio parameters (FM and AM modulation depth, RF carrier frequency and power, harmonic and spurious outputs), even simple two-way radio receivers have to achieve specified levels of sensitivity. The fundamental requirements of stability, selectivity and sensitivity in modern radio transceivers are still relevant today; they just get measured and managed in different ways.

The introduction of analogue cellular phones in the early 1980's introduced additional measurement requirements, partly because more RF channels needed to be measured (initially 1000 channels in TACS then 1321 channels in ETACS), but also because power control and handover protocols had to be made to work. Power control and handover stability was in turn dependent on predictable and consistent RF performance in the handset. Some AMPS phones produced in the early 1980's could drift in frequency by a kHz a year or more - an 8-year-old mobile could be 8 kHz off centre frequency, significantly degrading adjacent channel performance.

The digital 2nd generation GSM system introduced Frequency correction bursts as a mechanism for introducing long-term RF stability into the handset population (a short training burst from the base station broadcast channel is used by the phone to acquire frequency lock to within 0.1 PPM). GSM also took advantage of digital voice codecs and digital modulation. The voice codecs would, in the longer term, deliver significant voice quality improvements but in the shorter term proved to be sensitive to bit errors and bit error distribution in the radio channel. Over several years, improved radio planning and the introduction of advanced techniques such as pseudo-random frequency hopping, led to significant improvements in the quality of the radio channel. But it still remained essential that the RF basics such as uplink and downlink modulation quality had to be closely controlled.

The GSM handset test specifications were mostly covered by the Test Specification TS GSM 11.10. On casual reading, the bulk of GSM 11.10 concerned signalling protocols and it was true to say that unless phones conformed to the standard they would fail the conformance test, or rather the 140 official tests used in what came to be described as interim type approval. The signalling protocols covered synchronisation and registration, call set up, call maintenance and call clear down. Signalling protocols are essentially decision protocols based on the premise that if X occurs, Y should then occur within a specified time. The trick of course is to have some way of accurately establishing the value of X, which brings us back to handset hardware testing.

Successful GSM handover is dependent on the handset compiling a measurement report from its own serving base station and up to 5 adjacent cell sites. The handset has to be capable of accurately and continuously measuring RX level, RX quality and timing advance for reporting back to the network. The network then follows specific decision criteria to decide if and when a handover is necessary and it is up to the handset to execute the request. As networks become more and more congested and the radio environment ever more complex (e.g. hierarchical cell structures), the quality of the handover algorithm becomes an increasingly competitive weapon in the battle for network quality and performance. As such, it is only the 'second best' algorithms that get discussed in the committees, with leading companies keeping their best secrets to themselves. This task of 'Radio Resource Management' ensures that at any point in time each and every mobile on the network is on the correct cell. It is a never-ending task that gets more complex every year.

The practical point to make is that even if the rules of engagement are agreed, they only work if the hardware works. In GSM, early iteration handsets only just met the conformance specification for receiver sensitivity (-102 dBm for a 1 in 10^{3} bit error rate). Over the following 5 years, receiver sensitivity improved by an average of 1dB per year due to better components, better design and the performance benefits of volume production. By 1997, the average sensitivity of GSM handsets was –107dBm, 5 dB better than the conformance standard. The moral of the tale is that conformance standards establish a **minimum** performance benchmark. To be market competitive, handsets have to get progressively better year on year in terms of RF performance and it is this process which helps the networks to continue to improve.

So lets move on ten years to the introduction of UMTS handsets.

The initial focus has been on the stability of the standards rather than the stability of handset hardware. In December 1999, a 'frozen' version of W-CDMA Release 99 was published. But 'frozen' did not mean finished and in the four years since December 1999 there have been over 7000 non-editorial changes approved by the 3GPP standards committee. In order to accelerate the stability of R99 it is increasingly the case that any outstanding issues of omission or ambiguity within R99 are being deferred to future releases still open for this type of change. (Release 5 for testing and Release 6 for core requirements).

On casual reading, the RF and physical layer parts of the W-CDMA standard seem clearly defined, including the test procedures set out in 3GPP TS 34.121. But in practice it has proved advisable to measure some UE parameters more comprehensively than the standards suggest. An example would be measurement of the modulation error vectors and timing of the physical random access channel (PRACH). In R99 there are no tests specified for PRACH modulation quality and frequency error. This only assumed significance when it was discovered that some prototype handsets would not reliably talk to all node B's. The reasons for this compatibility problem are many but at least one could be related to the frequency capture range of the node B's. The specified UE maximum frequency error is .1PPM but not all UEs meet this all the time, and some node B's are more tolerant of errors than others. Thus we can see the beginnings of inter-operability problems.

Other known problems with PRACH bursts include errors in the timing of the start or finish of the burst as well as inconsistent or incorrect access slot and signature usage. The tests that currently exist in 34.121 for R99 will either ignore or be agnostic towards many of these issues. But when it comes to real network deployment where the network parameters do not match the often benign configurations used in testing, it is likely that interoperability and performance problems will develop which could lead to product recalls or compromises having to be made in the operation of networks. It is hoped that later releases of the UMTS test specification 34.121 will include more comprehensive tests in these and other areas, however it remains the reality that the R99 UMTS test standard – against which terminals are certified through the Global Certification Forum – will probably never be elaborated. The UE designer is then faced with having to look in later releases of the test standard to find those aspects which have been elaborated but which are not optional feature enhancements to later releases – rather they are fundamental features essential to any UMTS network.

In additional to the limited PRACH tests in R99 there exist other R99 issues related to lack of core requirements. An example would be UE transmit modulation. This is specified from max power down to–20 dBm but the system is expected to operate down to –50 dBm. At such low powers the UE error vector magnitude could well be substantially greater than the specified limit of 17.5% but there are no requirements or tests. A typical application of the use of low output power would be in a low power micro or picocell. A UE that had substantial problems with modulation quality at low power could wreak havoc with other users. For example, the UE may transmit at too high a power due to the network trying to deal with the high error rates at the lower powers. This excess power desensitizes the Node B receiver to the disadvantage of the compliant UEs. Thus we have an example of the fascinatingly complex Radio Resource Management issues which are fundamental to CDMA technology. RRM was and still is a challenge in GSM, but for UMTS, RRM is the factor which will make the difference between delivering on the promises of 3G or going out of business.

In summary, handset hardware performance continues to have a fundamental impact on network performance including signalling protocol stability. If the PRACH doesn't work, nothing works. If error rates are high, the network will try and compensate for the poor link quality and in the process will usually degrade someone else's link.

The examples given above highlight a couple of more general points about standards and conformance and performance testing.

Firstly, the correctness or completeness of a standard cannot be judged by the number of pages that have been published. In a standard as complex as UMTS it is impossible to foresee every possible pitfall. This knowledge only comes from practical experience, so despite its 30,000+ pages, there is probably as much not written about

UMTS as already written.

Secondly, testing against a large but still incomplete conformance specification is only a starting point and represents a **minimum** performance benchmark. The rule of thumb in GSM was that you were expected to achieve a handset cost reduction of 15 to 20% per year and a measurable gain in performance **over and above** the conformance standard. This expectation will also apply to UMTS handsets. So whereas today, the focus is on handset hardware **conformance** testing, this gradually shifts over time to handset hardware **performance** testing.

The RF and physical layer tests remain important because of the way in which RF and physical layer performance determines the performance and stability of **all** the upper layers of the protocol stack. And with the highly interactive nature of the CDMA system, the consequences of problems at the physical layer on even a few rogue handsets in a network can be catastrophic on overall system capacity and performance. The way in which CDMA systems softly degrade makes tracking down the source of problems very difficult.

It has become fashionable to focus on software testing as the big challenge but handset hardware testing and the closely related Radio Resource Management– the ‘glue’ that holds the air interface together - remain the fundamental foundation for achieving network and system stability.

About RTT Technology Topics

RTT Technology Topics reflect areas of research that we are presently working on.

We aim to introduce new terminology and new ideas to clarify present and future technology and business issues.

Do pass these Technology Topics on to your colleagues, encourage them to join our Push List and respond with comments.

Contact RTT

RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

If you would like more information on this work then please contact

geoff@rttonline.com

00 44 208 744 3163