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FRAMEWORK FOR THIRD GENERATION (3G) CELLULAR NETWROK DEPLOYMENT AND SERVICES OFFERING IN SINGAPORE

RESPONSE FROM NORTEL NETWORKS

Third Generation Mobile Communications

Abstract

This paper considers the spectrum aspects of terrestrial third generation systems and provides a high level overview of the standards which are being developed and how they are expected to be deployed. The concept of ‘hierarchical’ cell structures is introduced with reference to any of the 3G systems and typical spectrum allocations to each tier of the hierarchy are indicated. This concept is then mapped onto the spectrum which could be available in Singapore and the European countries to illustrate how a number of operators could share the spectrum. The cases of 4 and 6 equal spectrum packages are first introduced and finally a five package plan, as has recently been adopted in the UK is explained.

1. What is 3G?

Third-Generation (3G) systems presently undergoing standardisation will provide the wireless access network for future mobile communications. 3G comprises a satellite and a terrestrial aspect. In this paper, we will focus on only terrestrial systems. Among the initial questions to be answered are:

- How will 3G be different from what we have now
- Will they fit in with them?

2G systems, such as GSM and cdmaOne, have been highly successful in delivering voice and low-rate data services and are expected to remain operational for many years. Networks using these older standards will continue to be developed and upgraded with enhancements such as GPRS for GSM and IS-136 on the network side and EDGE for GSM and IS-136 or 1XRTT for cdmaOne on the access side. 3G systems deployed in additional spectrum will offer more advanced services and higher data rates until now associated only with fixed access. 3G will offer a new range of services with a consistent look and feel across a wide range of operating environments -- from full mobility to the office and home.

Furthermore, 3G has taken ‘global roaming’ as a key requirement, creating an increased market for internationally mobile users and potential for increased commonality of equipment -- especially user equipment (UE) -- with the associated economies of scale.

Our vision of the attributes 3G wireless systems offer is: specifically ubiquitous, seamless, with efficient wireless data capability, technology positioned well to intercept the ever-expanding data traffic of the fixed telecommunications sector.

2. Demand of 3G Technology

The explosive growth of the Internet and deregulation of the telecommunications industry are profoundly altering the competitive landscape for telecommunications operators. As wireless operations managers scramble to respond to demand with additional capacity, executives must carefully consider in their investment decisions the impact further price erosion and emerging demand for mobile Internet access will have on their businesses. It is recognised that profitability will depend on a network solution that is responsive to the sensitivities of voice quality and capacity, while at the same time delivering high performance Wireless Internet. This network must be readily scalable with revenue growth, minimise costs of operation and capital expenditures, and yet enhance revenue through the rapid deployment of new and competitive value-added services.

3. Multiple Standards

3.1 Overview of the main 3G standards

Three main standards are likely to be deployed in 3G spectrum, depending upon commercial and technical factors:

- Direct Sequence Wideband CDMA (UTRA) with an FDD and TDD mode
- Multi-carrier CDMA (cdma2000 3XRTT)
- UWC-136 (TDMA)

All these standards will bring increased efficiency to an operator’s network, both in terms of spectrum efficiency and improved handling of packet data -- both of which are becoming increasingly important. Within the last few months, the ‘Operators Harmonisation Group’ (OHG), with the support of various standards bodies, has worked to converge the main CDMA-based standards as much as possible.

Probably the most widely discussed change arising from this process was the reduction in chip rate of the W-CDMA system from 4.096 to 3.84 Mchip/s (15/16ths of the old rate). Also discussed were detail changes to the pilot structure and synchronisation methods supported to make a common platform possible and help improve the fit to a 5MHz spectrum block.

One key development which has not had so much publicity is that it will be possible to use W-CDMA or cdma2000 on both GSM-MAP- and ANSI-41-based core networks, and handover between the modes will be supported. For existing operators, this ensures a clear upgrade route to 3G will be supported . For new entrants, this increases the possible number of access/core network combinations.

Working groups are being formed to ensure the necessary ‘hooks’ are in place to support later extensions of the protocols. To facilitate multiple standards to co-exist in adjacent spectrum blocks, it is to be hoped that similar or equivalent levels can be set for the key RF parameters across the standards. For example, the receiver selectivity and levels of unwanted emissions which can be radiated from the antenna port will help determine the deployment ‘etiquette’ required between adjacent operators employing different access standards.

3.2 3G Carrier Spacing and Channel Raster

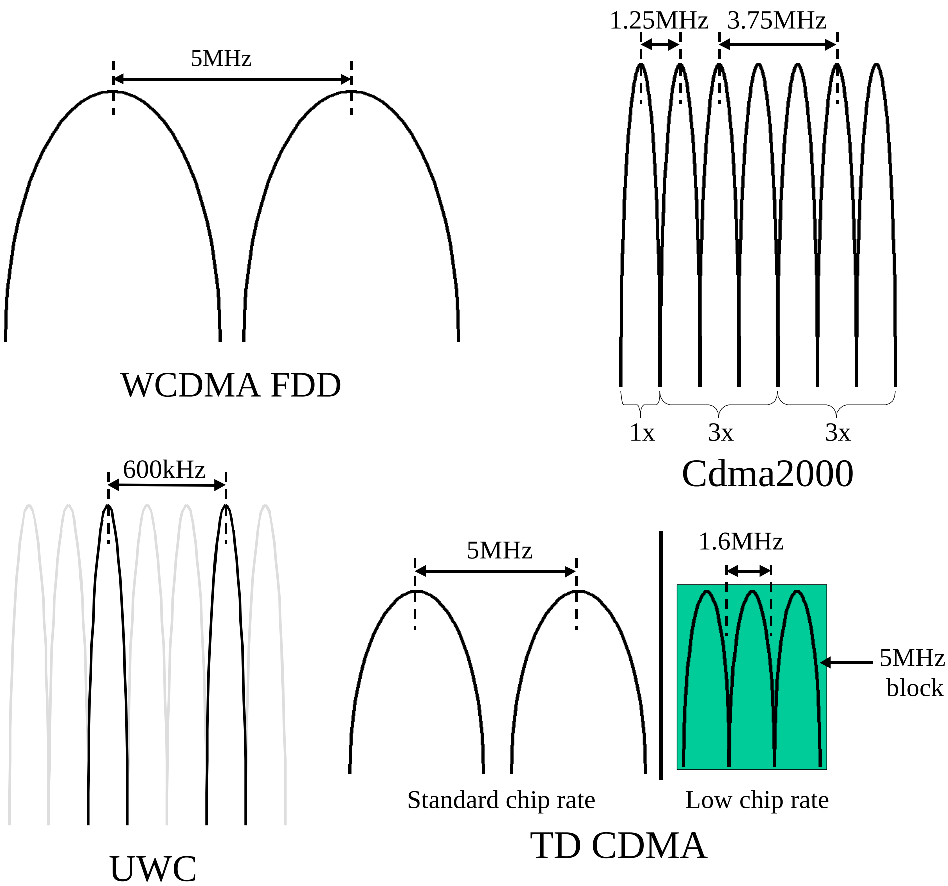


Figure 1: 3G Carrier Spacing and Raster

Within a 5 MHz allocation, each technology should accommodate its own guard band, so no additional ‘inter technology’ guard bands are expected to be required for systems to ‘co-exist’. The channel spacing required by the main 3G technologies are shown in Figure 1 and explained in more detail below.

The nominal channel spacing for W-CDMA is 5 MHz on a 200 kHz raster : intra operator the minimum carrier spacing may be reduced especially when systems are collocated. An inter operator spacing of 5 MHz is the minimum.

For UWC-136, a 200kHz-channel spacing is the norm, with the reuse pattern determining the actual spacing intra operator. For the example shown in Figure 1, every third possible carrier is active, resulting in a 600 kHz separation. A small guard band of one channel would normally be left at the edge of an operator's allocated block to reduce unwanted emission levels into a neighbour's allocation.

For cdma2000, the nominal spacing between carriers' 1XRTT is 1.25 MHz, and 3XRTT is 3.75 MHz on a 50 kHz raster. A guard band is normally left at the edge of an operator's spectrum allocation in the region of 625 kHz to limit spectrum over-spill.

For TDD mode following the recent OHG decisions, one TD-CDMA mode based on the UTRA TDD mode was agreed to be standardised. Within this mode, there are two chip rates -- a higher rate aligned with the FDD chip rate of 3.84 Mchip/s compatible with nominal carrier spacing of 5 MHz and a lower rate compatible with a nominal carrier spacing of 1.6 MHz -- thus permitting three carriers per 5 MHz block.

4. Current 3G Spectrum Allocations

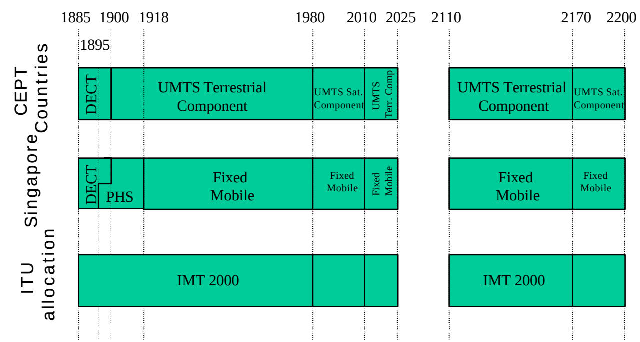


Figure2: Current 3G Spectrum Allocations

For 3G to flourish, new licensed spectrum will be required for public operator use. The process of identifying spectrum suitable for the global introduction of 3G, started in the early 1990's under the title 'IMT-2000', is nearly complete. Figure 2 shows the allocations proposed by the ITU (WARC-92 agreement) and those adopted for the CEPT countries and HK.

We are now entering the next critical phase :- sub-dividing the spectrum into useful packages. This must be completed prior to the award of 3G licences. Finland has awarded licences, Japan is expected shortly to do so, and several other countries such as the UK and Germany plan to award licences early next year (2000).

Since 3G systems are intended to operate in multiples of 5 MHz basic building block allocations, this will be used as the basis of the band plan designs. One key difference between 3G and 2G spectrum is that while public 2G spectrum was generally licensed in 'pairs', most regions adopting 3G will licence up to 35 MHz of unpaired spectrum in addition to 120 MHz of the paired spectrum. The consequence of this is that a TDD mode will be required to fully exploit the capacity of the spectrum available. In this section of the paper we will describe several different approaches to the sub-division of the '3G Spectrum' -- each of which has particular advantages.

5. Hierarchical Cell Structures

5.1 Concept

This section introduces the concept of hierarchical cell deployment to efficiently accommodate the wider differences in data rate and user type that exists in 2G networks. A stylised example of this concept is illustrated in Figures 3 and 4.

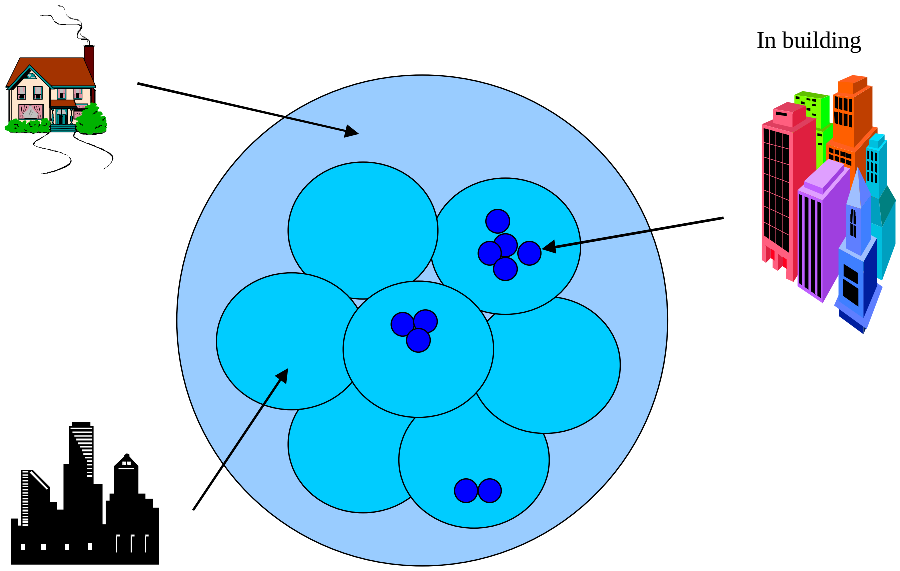


Figure 3: Typical Cell Structures

Given the limited amount of available new spectrum, the use of hierarchical cell structures based on the use of 'Macro' (M), Micro (m) and Pico (p) cells has been proposed. In this model, Macro cells carry the faster-moving wide-area traffic; micro cells carry the higher-data-rate pedestrian traffic, and Pico cells are deployed to cover 'hot spots' to relive capacity bottlenecks such as in offices or airports where user density is particularly high.

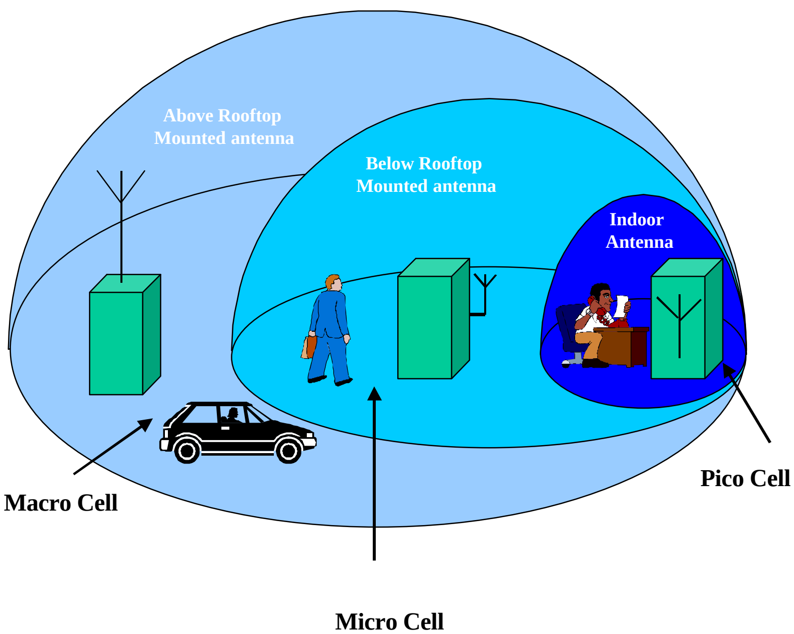


Figure 4: Applications and antenna positions of different cell sizes

Typically, Macro cells would have a range of 1 km or more, Micro cells a range of between 200 and 500 metres and Pico cells from a few metres to 100 metres.

5.2 Example Spectrum Allocation to Service Layers

Overall Spectrum Allocation	Macro	Micro	Pico	Scenario
15 + 15 plus 5	10 MHz (5 + 5)	20 MHz (10 + 10)	5 MHz (5)	1
15 + 15	10 MHz (5 + 5)	10 MHz (5 + 5)	10 MHz (5 + 5)	2
10 + 10 plus 5	10 MHz (5 + 5)	10 MHz (5 + 5)	5 MHz (5)	3
10 + 10	10 MHz (5 + 5)	10 MHz (5 + 5)		4

Table 1: Example Spectrum Allocation to Service Layers

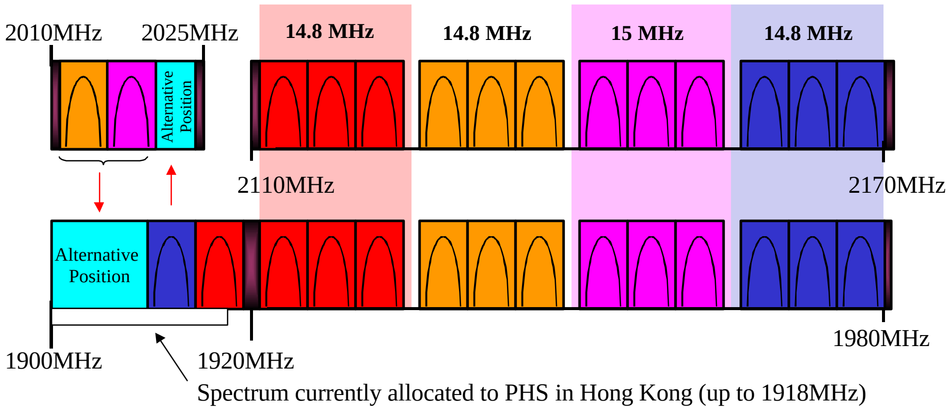
The table above provides an example of how existing 2G operators with various total new 3G spectrum allocations could sub-divide in order to deploy RF carriers in a hierarchical structure to increase the capacity/ sq. km of their access networks. The first three scenarios would allow an operator to build a three-tier structure with a broadband system. In the final example, the operator could only offer limited access to the higher data rates since no Pico layer can be provisioned. For a narrower-band system, a small amount of spectrum could be dedicated for this purpose at the expense of some capacity loss on one or both of the other two layers.

Therefore, Scenario 3 (10+10 plus 5) is the minimum allocation for permitting a hierarchical cell structure to be deployed using any of the 3G standards.

6. Possible Band Plans

Next we will turn our attention to how the spectrum available for 3G could be sub-divided, and we will provide examples of how between 4 and 6 packages could be allocated.

6.1 Four Licenses



Alternative positions are represented by a red arrow.

Figure 5: Example Frequency Plan for four licenses

Figure 5 shows how four nominally equal packages in line with Scenario 1 in Table 1 (15+15 plus 5 MHz) can be allocated from the potentially available spectrum. This is a straightforward plan giving up to four operators 3G spectrum and can be arranged to leave the ‘upper unpaired’ spectrum free. For example, ‘private applications’ such as TDD-based home base stations could be accommodated in the unallocated positions. Alternatively, if, as in Singapore part of the lower unpaired band is allocated to another service, such as PHS, the upper unpaired spectrum could be used to accommodate two or three of the unpaired blocks.

The following themes will occur in the allocation schemes we will consider:

- Contiguous blocks of paired spectrum have been allocated to provide flexibility in deployment and minimise the impact of adjacent operators
- Three packages have been ‘squeezed’ down to 14.8 MHz to accommodate a 300 kHz guard band at each end of the paired spectrum [1]
- The spectrum block on each side of the boundary at 1920 MHz between the lower unpaired spectrum and lower paired spectrum are included in the same block. This permits a single operator to manage the co-ordination issues of TDD interference from the band from 1915-1920 MHz (nominal) into the FDD uplink band starting at 1920 instead of forcing co-operation between competing operators
- A small additional guardband between the paired and unpaired spectrum at 1920 MHz will generally be required to take into account the 200 kHz channel raster used by UTRA. For UTRA, the minimum additional guard band will be 100 kHz due to the raster (400 kHz total), and the maximum permitted

6.2 Six Equal Licenses

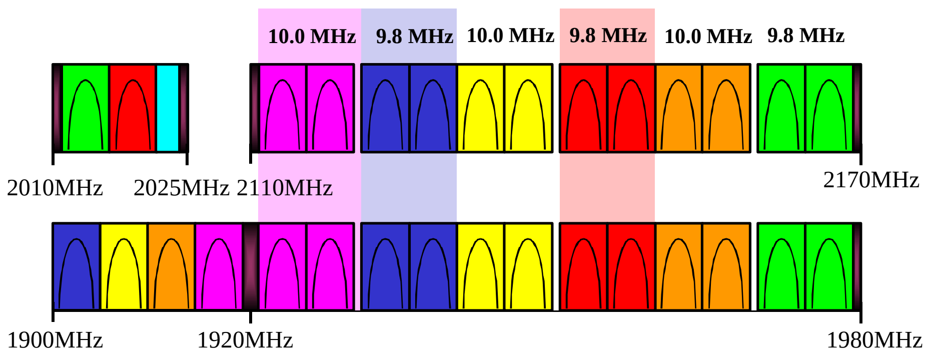


Figure 6: Example Frequency Plan for six equal licenses

Next, we consider the case of six equal licences of 10+10 plus 5 is shown in Figure 6. The three packages have been squeezed down to accommodate the guard bands, and all (or all but one) of the unpaired blocks have been allocated. The UMTS forum considered this scenario [2] for an all UTRA deployment case and determined that it would meet all the requirements for capacity with a 20% margin[1]. Although there may be some loss of flexibility for the operators in some cases, it is a viable plan if 6 operators are desired. As in the earlier example, a good TDD solution will be required as the network matures to satisfy the Pico layer traffic demand.

[1] The UMTS Forum used provisional figures for spectrum efficiency which may not reflect present understanding of best practice or advanced features.

6.3 Five Licenses

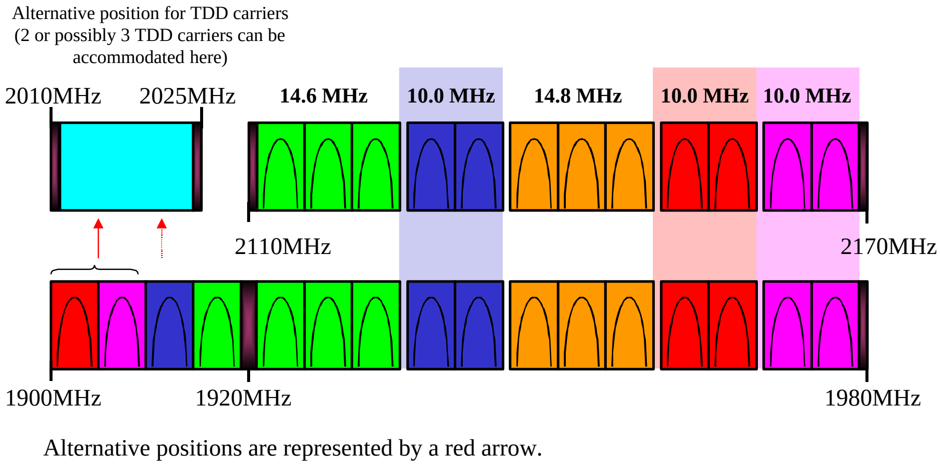


Figure 7: Example Frequency Plan for five licenses

Finally, we take a look at how five licences could be allocated. In the simplest case, we could use the plan for 6 licences and leave one package unused. This however, is a waste of spectrum and would mean the smaller packages would need to carry an average of 20% more traffic, eroding the margin for growth of usage. Therefore, we can consider mixing a number of the allocations we considered earlier to create five unequal licences. The plan in Figure 7 has been adopted in the UK to encourage a new entrant into the mobile market. The largest package of 15+15 plus 5 is reserved for a new entrant. Each of the five operators has at least three spectrum blocks. The three smallest licences have two FDD pairs plus a TDD; one block has three FDD pairs, and the largest block has three FDD pairs and one TDD block. For the three holders of the smaller licences, a 'high-grade' TDD mode standard will be required to service traffic demand in a mature network. The spectrum packages with the largest allocation of FDD spectrum have been squeezed to accommodate the small guard bands at the edge of the allocation. In this example, if we consider UTRA W-CDMA, it is possible for each operator to space its FDD RF carriers at 4.8 MHz, with an inter operator spacing of 5.2 MHz, and space the TDD RF carriers at 5MHz.

In UK and most of the Europe, the band from 2110 to 2120MHz has been designated for license exempt private applications.

7. Existing Operators Position

3G introduces a revolutionary new approach to communications which delivers services that will generate a new mass market for wireless technology. Initially, operators will use 3G as a new radio front end to existing GSM core network in order to gain a 3G license and hence more radio spectrum. 3G only operators will enter a highly competitive market with potentially high set up costs, hence slow to rollout services.

Regulatory constraints should be closely tied to licensing process. "Fair" process by auction will allow equal opportunity to new and existing operators to enter the market, depending on the investment capacity.

The other way to gain 3G spectrum is by "beauty contest" to ensure that the 2G operators have a fair chance to be 3G operators, based on their strong wireless experience. However, fair competition is a problem for regulators for future spectrum needs. In UK, the new entrants are provided with more spectrum. In France, beauty contest is being considered in the 1st phase and auction is being adopted in the 2nd phase of licensing process. Another consideration could be the regulators to allow the 2G spectrum to be used for 3G services in the future, when spectrum becomes the "bottelneck".

8. Timing of License Award & Service Launch

Both the local market demand and the readiness of the players drive the readiness of 3G services. In order to stay competitive in the market, it is believed that one need to be an 'early adopter' in the market.

In Europe, most of the countries are pushing for early start of 3G services with trial networks implemented by 2H 2000. Therefore, the specifications and 3G mobile stations will need to be ready prior to this date. The deadline to launch 3G services is 1st January 2002 in Europe. There are currently 4 licenses awarded within the Europe continent, with more to come in 1st Quarter 2000:

Country	Number of Licenses
Finland	4
UK	5 (Planned Feb 2000)
Netherlands	4 (Planned Mar 2000)
Germany	4 or 5 (Planned end 1999)

In Asia, Hong Kong and Taiwan are planning to start the 3G activities in line with the European timeframe.

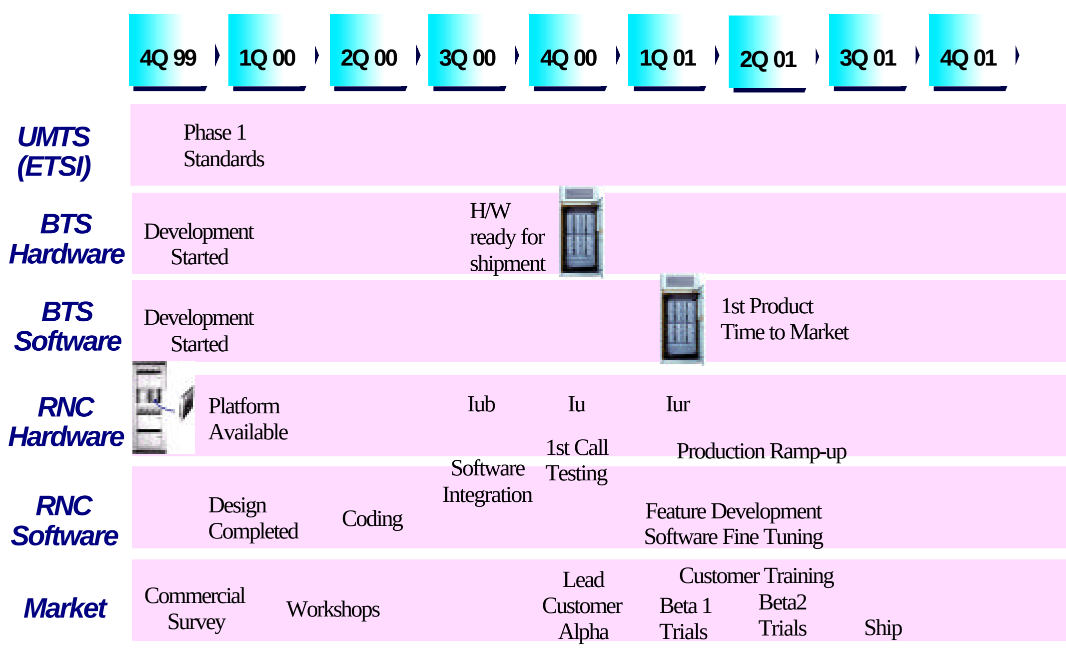


Figure 7: UMTS Development Timeframe

9. Conclusions

In this paper, we have introduced '3G' terrestrial mobile systems in terms of technical aspects and given some idea of how the new technology can be exploited..

We have described a three-tier hierarchical deployment as the probable method to be used by 3G operators to maximise use of the available new spectrum. We have discussed the spectrum requirements which result from the three-tier model and identified an allocation of 10 + 10 MHz paired plus 5 MHz unpaired as suitable. If no unpaired spectrum is available the minimum requirement would be 15+15 MHz although it may be possible for an existing operator to offer most services in a lesser initial allocation.

We have illustrated the spectrum available for 3G in the European countries and Singapore and have explained the need for high-quality 'robust' TDD systems capable of exploiting the unpaired spectrum to complement the initial FDD systems.

Finally we have given three examples how this spectrum could be sub-divided to provide 4, 5 or 6 viable packages.

10. References

[1] ERC Report [TG1/02] : Adjacent Band Compatibility between UMTS and Other Services in the 2 GHz Band
[2] UMTS Forum Report #5 : Minimum spectrum demand per public terrestrial UMTS operator in the initial phase. 8 September 1998.

11. About the Author

Keith Edwards was born in Ickenham, Middlesex, UK in 1962. He studied Electronic Engineering and received his Bachelors' Degree from the University of York in 1983. After graduation, Keith joined STC, later to become part of Nortel Networks, where he was engaged on numerous wireless-related projects. Those included Null Steering Antennas and the SmartBTS for GSM-1900. He is now part of Nortel Networks' global 3G team, helping shape the company's future products and concepts. His particular responsibilities include 3G TDD Systems and Spectrum Policy. Keith is a member of the IEE, a Chartered Engineer and named as an inventor on three Patents.

Keith Edwards can be contacted at keithe@nortelnetworks.com

12. Glossary

2G: Second-generation standards such as GSM, IS-136 and cdmaOne
3G: Standards which will be adopted as IMT-2000 family members
1XRTT: An evolution of cdmaOne with enhanced capacity and data capability
3XRTT: Multi-carrier evolution from 1XRTT with enhanced data capabilities
AMPS: Advanced Mobile Phone System (a 1G analogue standard)
ANSI-41: A U.S. Core network standard
CDMA: Code Division Multiple Access
cdma2000: Generic term for cdmaOne evolution covering 1XRTT and 3XRTT
cdmaOne: Name given to 'IS-95' cdma system
'co-exist': the magnitude of the interference anticipated is acceptable for satisfactory operation
DECT: Digital Enhanced Cordless Telecommunications
EDGE: Enhanced Data for GSM Evolution
ERC: European Radiocommunications Committee
FDD: Frequency Division Duplex
GPRS: General Packet Data System
GSM: Global System for Mobile communication (operates in 900, 1800 and 1900 MHz bands)
GSM-MAP: GSM- Mobile Application Part – the basis of the GSM core network
IMT-2000: The ITU concept for third-generation systems
IS-54: Known as Digital AMPS
IS-136: Interim Standard 136 - an enhanced version of Digital AMPS (IS-54)
'minimum carrier separation': spacing between carriers for them to co-exist
ITU: International Telecommunications Union
OHG: Operators Harmonisation Group
PHS : Personal Handy-phone System
RF: Radio Frequency
TDD: Time division duplex
UTRA: Universal Terrestrial Radio Access – the terrestrial portion of UMTS
UMTS: Universal Mobile Telecommunications System
UWC-136: A third -generation TDMA standard related to GSM and IS-136 evolution
W-CDMA: Wideband – CDMA

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