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IMPACT OF UMTS

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Introduction

At the time of writing this paper, the auction taking place in the UK for five UMTS[1] licences is certain to raise over £20 billion. The large sums involved have ensured an unprecedented level of media coverage for a process which hitherto has been a relatively low-key affair. Licences for UMTS have already been awarded in Finland and Spain, and many more countries have embarked on licensing.

The impact that the new networks will have on the environment and health has also not escaped the attention of the press. For example, many UK papers covered the comment “With the next generation of mobile phones there could be another 100,000 masts on the horizon”, made recently in Parliament during the introduction of a Ten Minute Rule Bill trying to impose restrictions on antenna siting.

The aim of this paper is to set out some of the factors which determine the density and form of cell sites for UMTS. I am certain that the other speakers in this conference session will amply address how further measures can be taken to minimise the visual impact of the antennas and their supporting structures through such techniques as mast sharing.

Multimedia Services

There are several key differences between UMTS technology and, say, GSM which result in a different set of network design and deployment requirements. UMTS offers[2]:

- optimised mobile multimedia service delivery
- multiple simultaneous services per user
- flexible bit rate (user rates of 8kbit/s to 2Mbits/s)
- quality of service (bit rate, bit error rate, delay and delay variation) to suit service
- packet or circuit switched operation.

Applications such as real-time voice or video telephony sessions are more demanding in terms of delays and delay variations than, for example, Internet access. Table 1 (derived from Ref. 1) shows some examples of applications corresponding to the defined UMTS traffic classes.

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[1] The abbreviation UMTS (Universal Mobile Telecommunications System) is used here synonymously with third generation mobile communications, or 3G. GSM is an example of a second generation, 2G, network.

[2] Some of these can also be partially achieved in a GSM network which has been extended to support GPRS.

Traffic class	**Conversational class**	**Streaming class**	**Interactive class** (best effort)	**Background** (best effort)
Typical application	Voice	Streaming video	Web browsing	Background download of e-mails

Table 1. UMTS Traffic Classes and Examples of Applications

So, in addition to the usual factors which determine coverage in a mobile network designed essentially for voice traffic (e.g. transmit powers, antenna heights, propagation environment, etc), with UMTS radio coverage and network dimensioning are dependent on the multimedia content being carried. This will be covered more fully in a later section.

Deployment Scenarios

Building continuous national coverage rapidly might not carry the same imperative for UMTS as it has for 2G networks. Incumbent operators winning a UMTS licence might choose to use their GSM networks to provide voice and a subset of multimedia services, and use UMTS specifically in areas where there is a concentration of multimedia type traffic (e.g. business districts, shopping centres, transport hubs, etc). It is sometimes argued that this “islands of coverage” deployment scenario is the right approach for UMTS, because concentrating coverage in selected areas means that maximum traffic can be captured at smallest cost.

Some operators might also provide “thin” continuous UMTS coverage for data services, co-locating UMTS basestations at existing sites as far as possible, while using GSM primarily for voice.

A new UMTS operator in the UK will, in principle, be in a similar position to the existing operators, since there is a time-limited regulatory provision to allow roaming onto others’ GSM networks. Despite this, many believe that there is a strong incentive for a new operator to become self-sufficient by building-out its UMTS network nationally to retain more revenue for itself.

The hybrid UMTS/GSM approaches above assume the availability of dual-mode handsets[3].

It is in this field of roll-out strategies and forecasting traffic mix and volumes where much of the techno-economic modelling used to support UMTS business cases has taken place.

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[3] The familiar term “handset” has been used, though the mobile station in a UMTS system might be physically quite different from a phone.

Standards

Third generation mobile communications in Europe will be based on the specifications produced within the Third Generation Partnership Project (3GPP)[4]. The initial release of these specifications, Release 99, was published by ETSI in February this year.

These specifications define two modes of operation over the radio interface, namely FDD and TDD (Frequency Division Duplex and Time Division Duplex, respectively). Both use a carrier spacing of 5 MHz, with the FDD mode using direct spread wideband CDMA (W-CDMA) technology and TDD using a combination of CDMA and TDMA.

FDD will be used where the UMTS spectrum is in paired duplex blocks while the TDD mode will, most commonly, be used in the parts of the UMTS radio spectrum which are not duplex paired (including possibly a block of licence-exempt spectrum).

Generally, TDD is suited to shorter range applications (such as pico cells), and has the advantage of being capable of supporting asymmetric up-link and down-link spectrum partitioning to enhance total capacity. However, since the majority of early systems are expected to use the FDD mode only, TDD mode will not be covered further in this paper.

Physical Constraints

With the UMTS radio frequency band (1900 to 2200 MHz) being close to GSM1800, it is possible to apply the same propagation models, such as COST231-Hata. Link power budgets have to be adapted for the UMTS technology to include soft handover gains, the information rate and required $E_b/(N_o+I_o)$ for the specific service being studied, etc.

The handset power classes are set in the specifications. The basestation (down-link) power levels are part of the licence conditions. For instance, in the UK the Radiocommunications Agency has provisionally specified the limits in Table 2 (Ref. 2).

Maximum EIRP per carrier	**Maximum average EIRP per MHz**
62 dBm	58 dBm/MHz

Table 2. Basestation Transmit Power

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[4] In principle, any of the five ITU-adopted 3G radio access standards could be used in Europe.

Capacity calculations and network dimensioning have to assume a mix of services, which apart from having different grades of service can also have different busy hours. It is necessary to abandon the usual methods based on Erlangs in favour of measures such as Mbit/hour/cell to determine cell loading. It is fair to say that the network planning approaches and tools for UMTS design are still in their relative infancy.

Macrocells

Cells in the macrocell layer are intended to:

(i) provide economical coverage in areas of relatively low traffic density
(ii) form an overlay layer to bridge gaps in radio coverage from cells lower in the cell hierarchy, and
(iii) support fast moving mobiles to prevent an excessive number of microcell handovers.

Within the constraints set by the system range, the topography-dependent radio propagation and the spectrum available, macrocell size can be designed to match the offered traffic load. In practice, the availability of suitable cell sites can determine the maximum macrocell density.

Tables 3 and 4 show the maximum cell to mobile distances and site separations (to provide "continuous" coverage) for a number of environments, calculated using a theoretical GSM model with actual equipment parameters. Tri-sectored sites were assumed. In each case the results are given for both outdoor and indoor quality coverage, assuming a building penetration loss of 17 dB.

Environment	Dense urban	Urban	Suburban	Rural
Maximum outdoor quality range	2.1 km	5.8 km	6.6 km	16.7 km
Maximum indoor quality range	0.7 km	1.5 km	2.1 km	5.4 km
Maximum site separation for indoor quality coverage	1.0 km	1.3 km	3.2 km	8.1 km (approx. 60 sites per 10,000 km^2 covered)

Table 3. GSM900 Ranges and Base Site Separations

Environment	Dense urban	Urban	Suburban	Rural
Maximum outdoor quality range	1.3 km	2.8 km	4.8 km	7.6 km
Maximum indoor quality range	0.4 km	0.9 km	1.6 km	2.5 km
Maximum site separation for indoor quality coverage	0.6 km	1.4 km	2.3 km	3.7 km (approx. 280 sites per 10,000 km^2 covered)

Table 4. GSM1800 Ranges and Base Site Separations

As an approximate comparison, the ranges and site separations in Table 5 have been calculated for the UMTS rural case using as many equivalent assumptions as possible.

	Maximum indoor quality range	Cell site separation	Number of sites per 10,000 km^2 (approx.)
Voice	4.6 km	6.9 km	80
144 kbit/s short delay	2.5 km	3.8 km	270
144 kbit/s long delay	3.1 km	4.7 km	180

Table 5. UMTS Ranges, Cell Site Separations and Number of Sites (Rural Environment)

With GSM and UMTS, the up-link effectively governs the range, principally because of the limited handset transmit power.

At bit rates higher than those shown in Table 5 the range decreases further, such that at 2 Mbit/s no more than a few hundred metres can be expected.

Tables 4 and 5 suggest that a GSM1800 system (rural site separations) should be able to support 144 kbit/s UMTS. However, in addition to the limitations of a theoretical model, these estimates are on the optimistic side since the UMTS calculations have assumed an unloaded system. In common with other CDMA systems, the maximum range shrinks as the loading is increased since each orthogonally-spread data channel introduces system noise. This effect is known as cell breathing.

Where a GSM network has been designed for capacity rather than coverage, more sites will be available, making the re-use of existing sites more practicable and possibly enabling higher bit rate UMTS services to be supported.

Unlike a GSM network, where capacity can be optimised for real traffic patterns by adding more transceivers to a cell then frequency re-planning, with UMTS the only variables are the number of sites and the number of carriers per site (which typically is a maximum of 2 or 3).

Microcells

Apart from simply being smaller, lower power basestations, one of the main concepts behind microcells in a city environment is to mount the antennas below roof level and use the buildings to confine the coverage, in order to allow frequencies to be re-used more often, leading to greater capacity.

When applied to UMTS, confining coverage reduces the amount of inter-cell interference (interference from surrounding cells operating on the same frequency), which can give a capacity gain of up to 40%. Because they are environmentally more acceptable, microcells also allow smaller site separations, and hence the higher bit rate UMTS services, to be supported.

Conclusions

Network planning for UMTS is made complicated by the wide range of multimedia services and the new set of design considerations introduced by the W-CDMA technology.

Where GSM1800 operators decide to re-use existing base sites for wide-area UMTS coverage (rather than handing over to GSM), at least a minimal service should be achievable without additional sites, but often with a lower penetration depth into buildings.

Microcells offer the opportunity for operators to achieve high capacity UMTS coverage, supporting the full range of services.

So, will 100,000 new masts be needed as mentioned in the Introduction? My belief is, thankfully, no. Certainly tens of thousands of basestations will be deployed for UMTS, but the majority will be microcell types.

References

1. 3GPP Technical Specification 3G TS 23.107, QoS Concept and Architecture
2. UMTS Auction Consultative Group, UACG(99)35, Confirmation of Proposals Relating to Multiple Technology Emission Limits

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