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Introduction

Development of standards for UMTS TDD mode has suffered from some lack of direction, due to the absence of a clear statement of requirements. As a result, manufacturers seem unwilling to commit to development of phones incorporating TDD mode, and some have expressed concern about the complexity of the present proposals. Although both licensed and unlicensed applications of TDD are envisaged, the different technical requirements imposed by co-ordinated or uncoordinated deployment have not been grasped. This paper aims to set out an operator's view of the requirements for TDD mode, and suggests a way forward in standardisation.

At first sight, network operators would be expected to be concerned primarily with coordinated operation in licensed bands. This paper suggests that uncoordinated operation and sharing of bands could also be very important to operators.

Challenges of TDD mode

A TDD mode is essential to make use of unpaired spectrum. Some limitations imposed by TDD operation must therefore be accepted as a result. The search for future expansion bands is concentrating on paired bands, but the options are limited, and it is possible that a substantial part any UMTS extension spectrum may be unpaired. This makes TDD mode potentially increasingly important for the future development of UMTS.

The major limitation of TDD is that because stations transmit and receive in the same band, measures must be taken to ensure to minimise interference between mobiles communicating with different base stations. Similarly, nearby base stations of a different network operating on the same or adjacent channels must be protected from one another. One tool in achieving such protection is synchronisation of networks to a common timing standard. While technical solutions exist to achieve this, they tend to have undesirable features. The small separation between the TDD bands and FDD uplink band also means that It is unlikely to be possible to collocate TDD and FDD cells, although this may depend on which frequencies are allocated to a given operator. There may also be problems in locating a TDD cell near an FDD cell of another operator.

Technical measures to achieve frequency sharing for unlicensed operation have yet to be considered. A CDMA system is particularly inappropriate for uncoordinated narrowband applications(e.g. home cordless phones) without major modification, due to the near/far problem and limited possibilities for dynamic channel allocation (DCA). TD/CDMA has some advantages in this respect, but may still not be ideal.

The need for guard times to accommodate path delay imposes an upper limit on range of TDD cells.

What should TDD be used for?

In view of the difficulty in collocation of FDD and TDD cells, the general industry view seems to be, quite reasonably, that the TDD band should be used mainly for indoor “pico” cell coverage. The nature of the service (public/private/hybrid?) and traffic (predominantly local - terminating in other extensions of a local system, or mostly routed out to a trunk network of some kind?) is much more difficult to determine. Some of the issues are discussed below. The business case for corporate indoor coverage will depend a lot on what spectrum is used, and the nature of the interconnect between the corporate system and the host network. In the light of fact that spectrum packages being proposed in some countries will give some operators access to 2 x FDD channels and 1 x TDD, it may be more attractive to use the licensed TDD spectrum in an outdoor microcell layer, to add capacity in traffic hot-spots in the wide-area network. The technology is still not well enough defined to give clear answers on the capacity of a single TDD channel, and whether it would be sensible to share it between microcells and indoor picocells. However, since the total spectrum available for TDD is significantly less than for FDD, it is clear that the cost of implementing TDD mode must also be low, to make it worthwhile.

Reports by Ovum/Quotient for the UK government on traffic demand and spectrum requirements were completed in early 1998 [1]. The conclusions of this work are heavily influenced by the assumptions about “Cordless Multimedia” traffic. The report on traffic demand admits to considerable uncertainty in this area. They define a “Cordless Multimedia system user” as: “A user who generates mobile traffic on a local-area base station. For example a user of a public pico cell in a shopping mall, a Cordless Multimedia cordless system *(sic)* or a home base station. We have taken this segment as users of local area UMTS infrastructure served with pico-cells, rather than a private wide-area mobile network.” They go on to state: “We forecast Cordless Multimedia systems based on the working population in each region as most Cordless Multimedia systems will be used in offices.” ***Ovum estimate that 70-90% of all UMTS traffic would be of this type.***

Because a single UMTS (FDD) carrier can only carry a single user at 2Mb/s, and then only at the expense of considerably reduced range and capacity in adjacent cells, they conclude that at least 2 carriers would be required in a picocell layer to support the “cordless multimedia” traffic. They estimate that remaining traffic would require one macrocell and one microcell carrier. These figures are based on using FDD carriers everywhere. If the picocell traffic was on TDD channels, they estimate a need for 3 channels (5MHz B/W each) to carry the traffic in any area.

The work by Ovum/Quotient does not distinguish between the traffic in private places such as offices and public places such as shopping malls or airport terminals. In terms of pure spectrum requirement, there may be little difference. To the operators, however, there is a very big difference.

In a public area expected to generate a high traffic density, all operators will expect to be represented. The traffic will be highly lucrative, like any other traffic in the wide-area network. On the other hand, there is perhaps little reason why users of such a part of a wide-area network would expect or need higher rate services than elsewhere. What’s the use of a videophone service that is only available at the airport? On the other hand, a great many users of slower services concentrated in a small area deserve addressing.

In contrast, the pico cell in business premises could have very different characteristics. There are likely to be several differences in the nature of the traffic and the way it is handled. A user may well expect additional high rate services when on home ground. He may also generate a lot more voice calls. However, these may mostly terminate locally in the company’s own internal PABX, intranet or other system. These are exactly the services for which the user will not expect to pay more than a nominal tariff. If the traffic is carried and switched in the same way as the rest of a wide-area UMTS network, the costs involved to the operator could be much the same as for any other traffic. The economics of this scenario do not look favourable. The operator could be using a large proportion of his UMTS spectrum to carry 90% of all traffic as a loss leader! A step forward would be to ensure that the UMTS network is specified to allow low-cost local switching of traffic. This could make a big difference to transmission costs in the network, but the capital investment in spectrum and in equipment on the user site might still be high. Models in which the building owner purchases and runs his own equipment, as he would a PABX, are potentially attractive, with a host network supplying interconnect and mobility management.

Another significant difference between the “corporate” and “public” picocell is that it is very unlikely that any corporate premises would require coverage by more than one operator. This suggests that some form of spectrum sharing would be an advantage in this case. Ideally, the sharing mechanisms should allow efficient usage of the spectrum by multiple systems in close proximity to one another, but not attempting to provide overlapping coverage. The "worst case" scenario would be a number of businesses operating on different floors of multiple-occupancy office blocks.

A subgroup of UKTAG, a UK industry group formed to advise government, attempted to identify the requirements for TDD mode, and the various ways in which it might be used in both private and public systems. Its report (ref [2]) was completed in November 1998. A second subgroup followed by considered some system architecture issues in interconnection of public and private systems, and reporting on the implications for standardisation (Ref [3]). This second report is not concerned with the radio interface.

So far, all of the discussion here has focussed on short range systems. Another potentially valuable use of the TDD mode and unpaired spectrum in UMTS would be to support relaying (ODMA). The direct application of relaying would be to provide coverage enhancement in a wide area network, and to allow enhanced data rates in areas where the path loss to the nearest base station would support only a low data rate service. There may be some limitations in how far this can be achieved, in order to meet the regulatory requirement that a terminal should not transmit before it has detected a network. Even if a direct path to a base station must be detected on the downlink, uplink coverage at high data rate may be enhanced by relaying. Since the individual links in a relayed system are all still short, only relatively low power would be required. Relaying technologies also have the potential to help to solve the spectrum sharing problems inherent in deploying uncoordinated business systems.

Operational requirements for TDD mode

Summarising the discussion above, the ideal TDD mode would have the following applications (in approximate order of importance)

- Use in a microcell layer to provide capacity in high traffic areas, both outdoor and in public indoor environments such as airports and exhibition centres.
- Enhancement of coverage via ODMA relays.
- Indoor corporate coverage. In this case, as discussed above, spectrum sharing is important, whether in unlicensed spectrum or licensed. ODMA should be used to assist in this and to enhance both coverage and capacity in this application. There are many options in this area concerning who owns and runs what part of the equipment, in whose spectrum, and with what relationship to the hosting mobile network. (e.g. Is the corporate coverage part of the host network, or just a roaming partner?). See Reference [2] for a discussion of the options. It will be important to identify a clear set of options that need to be supported. Reference [4] develops some of the ideas from [2] and suggests some priorities. Greater traffic per user and greater use of high data rate services is anticipated in this environment than elsewhere.
- Handover supported between TDD/FDD mode (Some aspects of this requirement are also considered in [2])
- In the longer term, to enable effective use of any additional unpaired spectrum allocated in WRC2000. This will probably increase the requirements to support larger cells and wider area coverage, as cositing with FDD sites in a different band may be no longer a problem.

Technical requirements for TDD mode

To support these applications, the ideal TDD mode would have the following characteristics:

- No need for synchronisation of base stations to an external timing source (though "self synchronising" solutions which do not rely on an external timing source may be considered)
- High spectrum efficiency maintained with minimum planning and in uncoordinated (spectrum sharing) environments, and when other TDD or FDD systems are deployed in adjacent channels. This implies the need for techniques which reduce the possibilities of interference by dynamic resource assignment and which offer suitable escape mechanisms to avoid interference if it occurs.
- Low cost addition to FDD handsets, with minimal additional hardware.
- Small, low cost base stations
- Support for relaying for coverage enhancement (and interference reduction).
- Ability to adjust balance between uplink and downlink traffic in each cell independently.
- Low power, short range limitation is acceptable in early implementations to achieve low cost, with an evolution path to longer range in later development. Similarly, it is not essential that initial implementations support high speed users or large delay spreads.

Limitations of existing TDD proposals

The main limitations of the existing TDD proposal are perceived to be:

- Insufficient consideration has been given to robust performance in uncoordinated scenarios
- Efficient DCA procedures are required to achieve adequate spectrum efficiency
- Cost/complexity may be too high for relatively easy channel conditions (small cells, low speed users, low delay spread)
- Systems in adjacent channels need to be synchronised

Summary

The best use of an exclusive allocation of a single TDD channel is probably to add capacity with indoor cells in public places (stations, airports, exhibition centres, shopping centres) and outdoor microcells.

The business case for provision of indoor pico-cell coverage to corporate customers depends strongly on the application of suitable technology. Some estimates suggest that 90% of all traffic could originate in such locations. For this reason, it is important to achieve development of a TDD mode that would work well in uncoordinated deployments where spectrum is shared, such as will arise in the UMTS licence exempt spectrum.

A set of requirements for the ideal TDD mode has been outlined. To achieve this goal, considerable standards work will be required both on radio interface and network aspects.

Conclusions

Since manufacturers will be concentrating on delivering FDD products for early system deployment, it is not essential to complete TDD standards in 1999. However, to make good use of unpaired spectrum, it is important to have a good TDD standard, which meets the requirements outlined above. In view of the limitations in the existing proposals, further study should be devoted to TDD mode, with the aim of having a comprehensive set of standards available by late 2000.
Key areas for further study are:

- Mechanisms of dynamic resource assignment and interference avoidance to maximise spectrum efficiency in uncoordinated environments.
- Use of ODMA relaying
- Simplifications that might be achieved by supporting only short range, low delay spread links with slow moving users.

8. References

[1] Study into Spectrum Requirements for UMTS, Market Demand and Traffic Requirements, Interim Report (final version), 20 January 1998, Quotient Communications, http://www.radio.ac.psiweb.com/documents/quotovum/market.doc

[2] "Requirements for UMTS TDD and Private Systems", UK TAG doc 65/98, 27th November 1998.

[3] "Standardization Scenarios for UMTS TDD and Private Systems", UK TAG doc 73/98, 22nd January 1999.

[4] "The role of, and issues related to, UMTS Licence Exempt Applications", Graham Crisp ,UMTS '99 IBC Conference, Monte Carlo, Monaco, June 1999