RTT TECHNOLOGY TOPIC
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LTE TDD

An argument can be made that a time division duplexed (TDD) radio layer would be more efficient at handling mobile broadband data traffic than present FDD networks.

In terms of traffic handling a TDD radio layer can be made to be asymmetric as required

As the radio channel is reciprocal (the same frequency is used on the uplink and downlink) it is easier to characterize the channel. This in turn makes it easier to extract some peak data rate gain from MIMO systems. It is also easier to adaptively noise match the receive chain and power match the transmit chain.

At radio planning level there is no need for a duplex gap. This releases additional spectrum.

A traditional FDD duplex band plan is shown below. The duplex gap keeps the TX power from one set of users getting in to the receive band of another set of users. The duplex spacing keeps locally generated transmit power out of the receive path within a mobile phone or mobile broadband device.

Other users	Guard band	Operational bandwidth lower duplex	Duplex gap	Operational bandwidth upper duplex	Guard band	Other users
			Duplex spacing			

In a TDD system the function of duplex spacing is performed in the time domain by ensuring that transmit time slots do not overlap receive time slots. The function of the duplex gap can only be achieved in the time domain if all networks are synchronised together. Specifically the frame structure configuration needs to be coordinated between adjacent cells to avoid simultaneous TX and RX on the same frequency at the same time.

Even if inter network synchronisation is achieved, users in different networks may have varying asymmetry which means that one set of users TX slots overlap another set of users' receive slots. The assumption here is that there is generally enough physical distance between users to mitigate any interference effects. If interference does occur it is managed by handing over to other time slots or channels.

Both WiFI and Wi Max use TDD and substantial licensed TDD spectrum has been allocated in the bands listed below.

Band	Frequencies MHz	Total Bandwidth MHz	Deployed in
33	1900 - 1920	20	
34	2010 - 2025	15	China
35	1850 - 1910	60	
36	1930 - 1990	60	
37	1910 - 1930	20	
38	2570 - 2620	50	
39	1880 - 1920	40	China
40	2300 - 2400	100	China
WiFi (unlicensed)	2400 - 2480		
Total bandwidth		365 MHz	
		305 MHz excluding overlaps	
		150 MHz excluding China	
		230 MHz including WiFi	

China has pursued its own standards with **TD SCDMA** and band allocation policy with Band 34 at 2010 to 2025 MHz, Band 39 at 1880 to 1920 MHz and Band 40 at 2300 to 2400 MHz. The assumption is that TDD LTE would also be supported as an option in Bands 38, 39 and 40.

China is one of the few countries with sufficient market scale to support a nationally specific standard and nationally specific band allocations. However this does not necessarily mean it's a particularly good idea.

Generally it can be stated that non standard standards and non standard spectral allocations have hampered the pace of past progress. The decision by Japanese regulators in the late 80's/ early 1990's to introduce PHS (an alternative to DECT and the UK's ill fated CT2 cordless standard) and PDC, a non standard implementation of GSM into non standard spectrum at 800 and 1500 MHz was designed to create a protected internal market which could be used by local vendors to amortise R and D and provide the basis for innovation incubation.

In practice it proved hard to translate this innovation into global markets and the R and D opportunity cost made Japanese handset vendors and their supply chain less rather than more competitive internationally. Korean vendors have faced similar challenges from nationally specific mobile broadband and broadcast standardisation. This has introduced unnecessary opportunity cost without a proportionate market gain.

The decision might be justified on the assumption that TDD will become more dominant as a mobile broadband bearer but several caveats apply.

TDD does not work particularly well in large cells as additional time domain guard band needs to be introduced to avoid intersymbol interference between transmit and receive time slots.

TDD does not work particularly well in small cells as base stations and users within a cell radius are likely to be closer together and therefore more likely to create mutual interference. This will be particularly noticeable with more extreme duty cycles for example when some users require uplink rather than downlink asymmetry.

As a prior example of this, the three PHS networks deployed in Japan in the mid 1990's were not inter synchronised. PHS networks were also deployed in China Taiwan and Thailand but never gained a more international market footprint. This was partly due to the intersymbol interference issue but also due to the fundamental fact that TDD devices have poor sensitivity. Power in transmit devices does not disappear instantaneously and substantial residual power can still be visible within the RX time slots. This does not matter when the duty cycle is relatively light, for example in a basic GSM voice path where only one slot in 8 is transmitting. It certainly matters if the TX duty cycle is higher which in many mobile broadband cases it will be. If the asymmetry is changing rapidly over time the signalling bandwidth will also become disproportionate.

So in practice any theoretical gains available from TDD will disappear in implementation loss. TDD may provide higher headline peak data rates but the average data throughput will be lower. TDD next to a LTE FDD receive channel will also be particularly bad news both at network level, base station to base station, and in the user equipment receive path. Given that it is unlikely that FDD will disappear for the foreseeable future, most user equipment will need to be dual mode so any potential component savings, eliminating duplex filters for example, would not be possible. Although the RF specifications are similar they are not the same and will incur additional conformance test time and cost. As always the impact on user equipment cost and performance tends to get overlooked or ignored.

Even at a system level it is arguable whether there is any efficiency gain. The argument is that if the uplink is lightly loaded in an FDD system then valuable bandwidth is being wasted. However all that happens is that the noise floor at the e node B reduces. This improves the performance of all other FDD uplinks in the cell, reducing power drain for all users served by the cell site.

So you might ask why TDD appears to work so well in WiFi. The answer is that WiFi is only spectrally efficient and energy efficient because it is low power, 10 milliwatts of transmit power from the UE rather than 125 or 250 milliwatts in TDD LTE. The occupied channel bandwidth of WiFi at 2.4 GHz is 22 MHz with a channel spacing of 25 MHz within 80 MHz of operational bandwidth so that's three channels within 80 MHz. This is not in itself efficient. The efficiency comes from the channel reuse that is in turn a function of the low transmit power. There is some trunking gain achievable from a 20 MHz channel but much of this disappears if bi directional differentiated quality of service needs to be supported.

It is hard to avoid the conclusion that TDD at least for general use within licensed spectrum is one of those technology cul de sacs that the industry has managed to drive into with no reverse gear engaged.

We would suggest the combination of reasons outlined above explain why wide area TDD Wimax networks are not performing as well as expected as offered traffic loading increases.

Other uses for LTE TDD – LTE ATG networks?
However TDD could be useful for other things.

One option might be to provide an air to ground (ATG) link from commercial airliners to ground stations to backhaul in flight WiFi traffic. This is already done in the US using **EVDO channels in the 800 MHz band for the uplink and downlink.**

Given that terrestrial cellular antennas generally point sideways rather than upwards there are obvious opportunities to get vertical reuse of spectrum in a rather similar way to ATC networks **(discussed in last month's technology topic)**

LTE R for railway communication systems?

Alternatively some of the presently under utilised TDD bandwidth could be reused to provide track to train and passenger connectivity including backhaul to and from on train WiFi. Train to track communication has been a problematic application sector. 4 MHz of duplex channel allocation immediately below the 900 MHz cellular band was allocated to GSM R some years ago to be used by European train companies. GSM R takes the GSM physical layer and adds functionality such as priority, pre emption and group calling.

There has never been sufficient market volume to justify significant investment in user equipment and or network hardware which remains expensive when compared to standard GSM product and adoption has been frustratingly slow. Although TDD might not be considered ideal for fast moving trains with Doppler shift at 500 kmph this is in practice a highly predictable communications environment which can be accurately modelled. LTE R could be a plausible technology for track to train and could double up to provide customer connectivity. Present train WiFI systems backhaul over GPRS bearers but LTE TDD could provide significant additional bandwidth at relatively low cost. A paper on LTE R is available **here.**

Summary
The industry has stumbled into allocating and auctioning TDD spectrum much of which will either never get used or will end up being used inefficiently. Not for the first time spectral allocation policy has been set and implemented without sufficient consideration of the practical technical limitations of the technology being deployed both in terms of wide area and local area broadband TDD connectivity.

More alarmingly there seems to be an emerging consensus that we need more rather than less TDD bandwidth in the superficial belief that TDD is somehow a more spectrally efficient and more energy efficient than FDD when handling highly asymmetric and or asynchronous data. There is minimal contemporary engineering evidence to support this view and much historical experience to suggest that the opposite is true. If something is not technically efficient it is unlikely to be commercially efficient.

LTE TDD might seem superficially attractive on the basis of apparent market potential in China but the opportunity costs of servicing one market are substantial – PHS and PDC in particular diluted Japanese vendor R and D effort just at the time when that effort needed to be focused on mainstream markets. Vendors with exposure to LTE TDD risk repeating that past mistake. The Chinese are nothing if not pragmatic and will drop TDD if better options are available (which they already are).

The opportunity – trains and boats and planes?
TDD may however have other application opportunities where the radio layer can be shown to be both technically and commercially efficient. LTE ATG and LTE R may be two areas where application added value may be realisable in the longer term. Similarly TDD WiMax is being used with considerable success in environments such as off shore oil and marine, maritime and naval communication closely

integrated with WiFi on board connectivity. Trains and boats and planes may just be the sweet spot for vendors with LTE TDD or WiMax TDD user equipment and network expertise.

LTE Study from RTT

RTT have produced a major 70 page study on LTE user equipment and LTE network economics. The study is written by RTT with statistics and economic modelling from **The Mobile World** and is sponsored by **Peregrine Semiconductor** and **Ethertronics.**

The study, 'LTE User Equipment, network efficiency and value' is available free of charge from the linked web site.

www.makingtelecomswork.com

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An additional level of detail on this topic and related topics can be accessed via the **Resources section** of our linked web site **www.makingtelecomswork.com**

www.makingtelecomswork.com provides a cost and time efficient way in which telecommunication engineers, product managers and policy makers can access **technical information and advice not readily available elsewhere in the public domain.**

The web site also provides information on RTT workshops, **Making Telecoms Work Europe**, **Making Telecoms Work Asia** and **Making Telecoms Work in the US.**

The workshops demonstrate how engineering issues can be practically resolved and how performance gains and cost savings can be achieved.

European work shops are held at the Science Museum in Kensington West London**. Information on the next workshop is available here.**

A number of sponsorship opportunities are available linked to the web site and related Science Museum telecom industry educational initiatives.

If you would like more information on these opportunities please e-mail **geoff@rttonline.com** or phone **00 44 208 744 3163**

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