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Cordless and cellular convergence

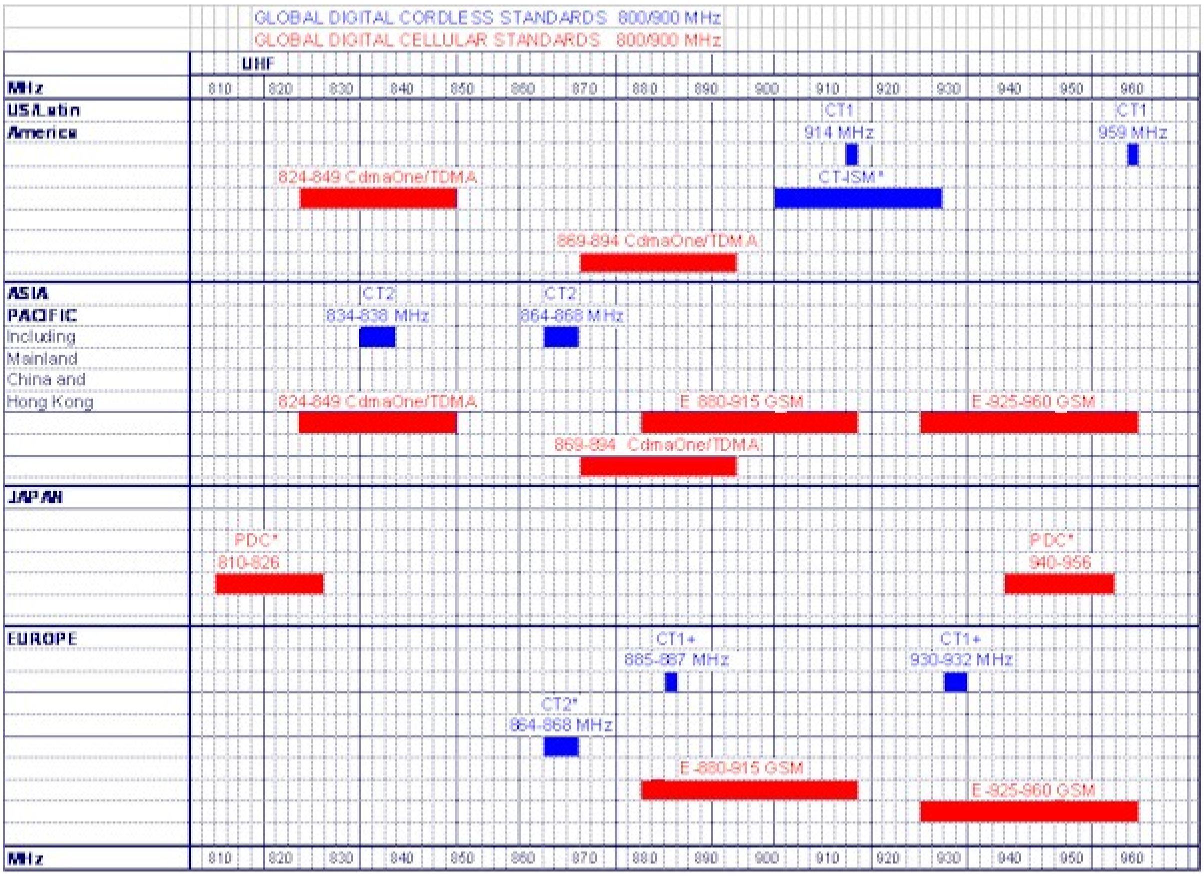
Cellular and cordless air interfaces are progressively converging. GSM GPRS and the DECT data profiles will both be delivering packet switched multi-slotted bandwidth on demand with data rates up to 2 M/bits. Why bother with two parallel standards when the final end product will be (more or less) the same.

In reality the historical difference between cellular and cordless air interfaces has been that cellular air interfaces have been developed and optimised for duplexed spaced frequency allocations, digital cordless air interfaces have been developed and optimised for simplex frequency allocations using time division rather than frequency division duplexing.

The advantage of simplex frequency working has traditionally been that the architecture of the phone can be made simpler and theoretically lower cost. The disadvantage for digital cordless systems used in simplex frequency allocations (also sometimes described as 'non-paired spectrum') is that the range of the phone (coverage and/or cell radius) is limited by the time space (guard band in the time domain) between the Rx and Tx time slots. A DECT or PHS phone, even if high powered, suffers unacceptable intersymbol interference in a wide area cell.

Thus the air interface is in practice the product of the frequency allocation. Figure 1 shows the frequency allocations for digital cellular and digital cordless (CT2) at 900 MHz, Fig 2 shows the frequency allocations for digital cellular and digital cordless at 1800 MHz. Figures 2 and 3 also show the IMT 2000 allocation for 3G (third generation) technologies. Note that not only does DECT have 20 MHz of spectrum allocation but also that the spectrum is immediately proximate to the 20 MHz allocation for TD-CDMA (time division duplexed CDMA), which in turn sits just below the lower band of the IMT2000 W-CDMA (Wideband CDMA) allocation.

Figure 1



GLOBAL DIGITAL CORDLESS STANDARDS 800/900 MHz
GLOBAL DIGITAL CELLULAR STANDARDS 800/900 MHz
UHF
MHz
810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960
US/Latin America
CT1 914 MHz
CT1 959 MHz
824-849 CdmaOne/TDMA
CT-ISM*
869-894 CdmaOne/TDMA
ASIA PACIFIC Including Mainland China and Hong Kong
CT2 834-838 MHz
CT2 864-868 MHz
824-849 CdmaOne/TDMA
E 880-915 GSM
E-925-960 GSM
869-894 CdmaOne/TDMA
JAPAN
PDC* 810-826
PDC* 940-956
EUROPE
CT1+ 885-887 MHz
CT1+ 930-932 MHz
CT2* 864-868 MHz
E-880-915 GSM
E-925-960 GSM

Figure 2

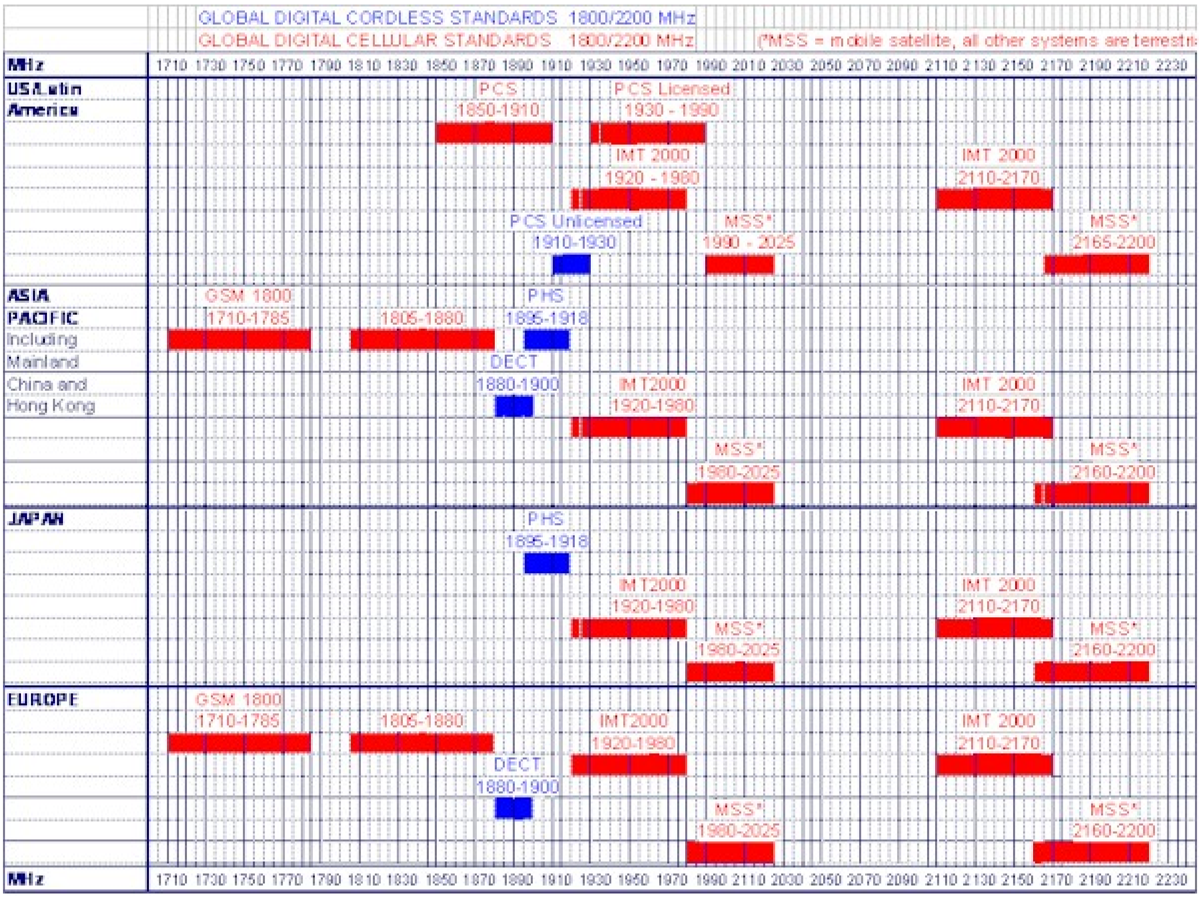


Figure 3

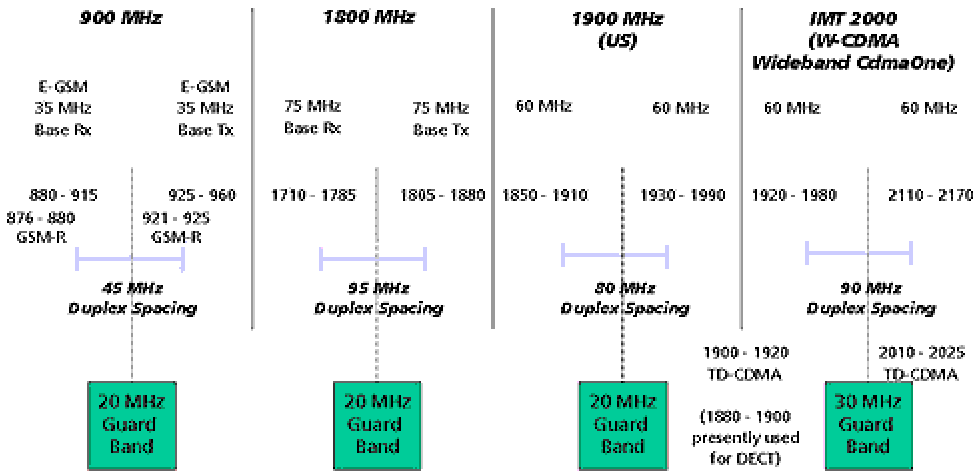


Figure 3 shows how all the allocations fit together. 20 MHz of DECT from 1880 to 1900 MHz, 20 MHz of TD-CDMA from 1900 to 1920 MHz, the lower paired band for W-CDMA from 1920 to 1980 MHz, 30 MHz of spectrum from 1980 to 2010 MHz for the ICO lower band (satellite), a further 15 MHz of non-paired spectrum from 2010 to 2025 MHz, the upper band of W-CDMA from 2110 to 2170, the upper band for ICO from 2170 to 2200 MHz.

Figure 4

Segment	Frequency Range	Allocated Use
Segment 1	1800 – 1900	TDD non-paired now used for DECT
Segment 2	1900 – 1920	TDD non-paired
Segment 3	1920 - 1980	FDD paired with Segment 6 wide are mobile
Segment 4	1980 – 2010	FDD paired with Segment 7 mobile satellite
Segment 5	2010 – 2025	TDD non-paired
Segment 6	2110 – 2170	Paired with Segment 3
Segment 7	2170 – 2200	Paired with Segment 4

Adding the DECT spectrum to the TDD non-paired spectrum gives 20 MHz + 20 MHz + 15 MHz, ie 55 MHz of unlicensed available bandwidth, the only limitation of the spectrum being that being non-paired, it is best suited to local area rather than wide area application – domestic LAN's, corporate LAN's, industrial LAN's, campus LAN's and/or wireless local loop.

Although this is a big market to address, there is still a clear need to take the DECT (and PHS) air interface and look at ways in which the access protocols can be developed to become part of (or integrated with) 3G TD-CDMA.

Assuming that ETSI and ARIB could collaborate together, there is a compelling argument to take the DECT and PHS air interfaces and combine the virtues of both standards. PHS for example has a back to back protocol which allows handsets to talk to each other independently of a base station – equivalent to TETRA's direct mode operation. A box of phones delivered on to site provides an instant network – back to the good old days of PMR short term hire except now the instant virtual network (IVN) will be TCP/IP compliant. Given that there are presently proposals to develop a new modulation standard for DECT to support the 2 M/bit data rate, now is the obvious time to bring together the DECT and PHS standard into common 32 k/bit, 64 k/bit, 128, 512 k/bit and 2 M/bit circuit and packet switched bearers. From there onwards, it is a relatively small step (patent litigation permitting) to add a CDMA multiplexed layer for additional traffic discrimination capability.

Which brings us on to a fundamental point. For the past 30 years, our industry has focussed (some would say obsessively) on the 'physical layer' air interface.

However, as MIPS (processor horsepower) and memory have migrated to the network edge (in wireless terms this includes the handset), added value has followed and this value is based on application layer rather than physical layer processing.

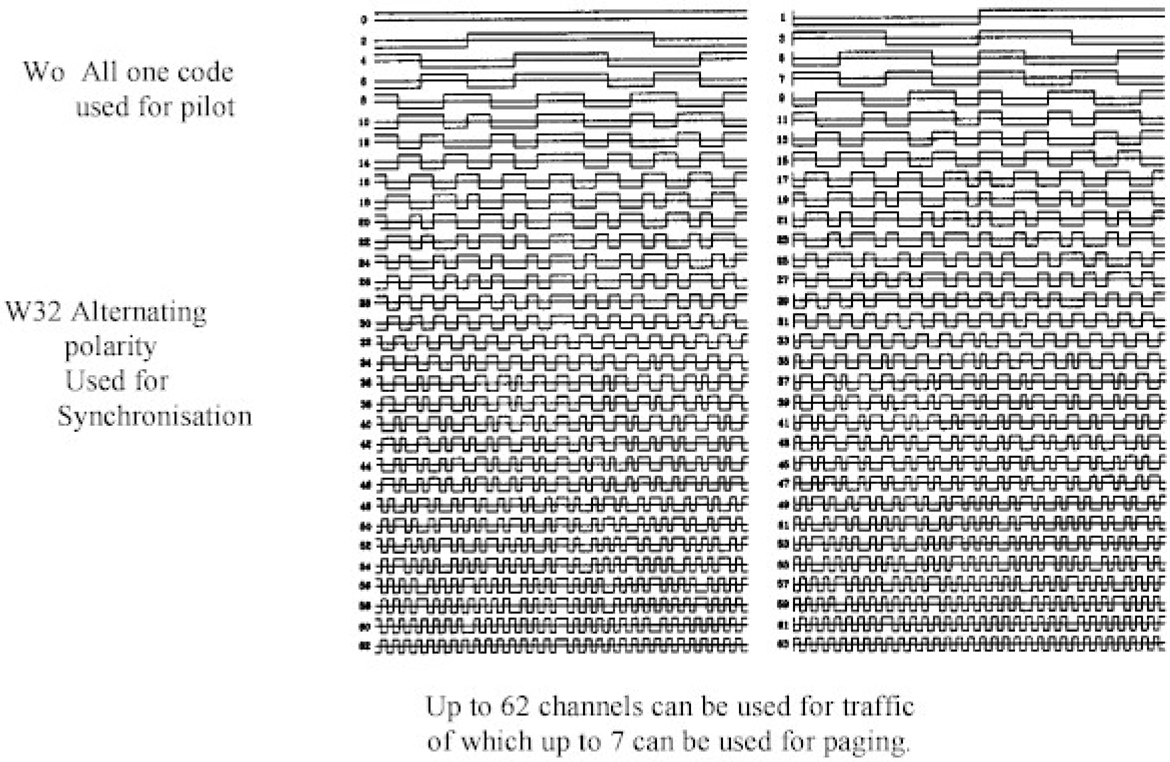
Application layer added value is driven by the need to independently prepare and pre-process 5 traffic mix products – voice, image, video, text and bulk file transfer prior to over-the-air transmission (the physical layer).

Compression is one example of application layer added value. Each of the traffic mix products can be compressed in different ways depending on the local MIPS (processing horsepower) and local memory available (which in turn is driven by cost and power budget limitations). Typical voice compression ratios for example range between 8 to 1 (digital cellular) and 20 to 1 (TETRA), typical text compression rates are between 4 to 1 and 8 to 1, typical image and video compression ratios can range from 10 to 1 to 500 to 1 (exotic fractal compression).

The compression ratio and compression technique used (lossless or lossy compression, interframe and intraframe compressions) dictates whether the traffic will be error sensitive or error tolerant and/or delay sensitive and delay tolerant. So we now have 5 traffic types (voice, image, video, text and bulk file transfer) all with different levels of error and latency tolerance, all of which need to be treated differently on the air interface and we have ended up with two multiplexing layers, one at the application layer and one at the physical layer.

So what does this have to do with DECT or cordless air interface evolution? Well, in 3G TD-CDMA and W-CDMA, the grand intention is to try and map application layer multiplexing on to the physical layer multiplex using 'traffic codes'. Figure 5 shows how channel discrimination is provided in present day 2G (second generation) CDMA – 64 Walsh codes (more or less orthogonal codes) are used to provide a pilot channel, a synchronisation channel, some paging channels (up to 7) and approximately 55 other channels on to which are loaded 'X' numbers of users who in turn are discriminated from one another by ‘user specific long codes'. In the receiver, the trick is first to lock on to the Walsh code to decorrelate the channel energy of interest, then within that to channel lock on to the long code to correlate the user energy of interest.

Figure 5



The 3G W-CDMA and TD-CDMA proposals take this processing one stage further by adding 'traffic codes' so that users can uplink or downlink different types of traffic which can be independently processed (and by implication) optimised across the air interface – the only difference between W-CDMA and TD-CDMA is that W-CDMA will be optimised for wide area networks, TD-CDMA will be optimised for local area networks. In an ideal world, both air interfaces would share common modulation, multiplexing and coding protocols through with TD-CDMA retaining time division duplexing and time division multiplexing.

So we now have an evolution route for DECT (and potentially PHS), which ideally would involve a convergence of modulation, multiplexing and coding with the only fundamental difference between cordless and cellular being the range restriction inherent and implicit in the non-paired frequency bands and the retention of time division duplexing and time division multiplexing in TD-CDMA.

The challenge will then be how to implement and manage the integration of (cordless **and** cellular) application layer and physical layer processing – application layer and physical layer convergence.

The two key deliverables in this integration process will be discrimination and determinism.

Discrimination as we have pointed out, is the ability to discriminate and distinguish between different traffic types on a per user basis – the end result is that a user should be able to send and receive simultaneous voice and data (the data being a mixture of image, video, text and bulk file transfer).

In wireline applications, this discrimination is or can be achieved by using ATM – asynchronous transfer mode. ATM is a mechanism (transport protocol) for taking essentially asynchronous mixed traffic and mapping the traffic on to a synchronous bearer delivering bandwidth on demand which can adapt to a user bit rate requirement that by its nature is changing.

ATM is designed for and is used on time domain multiplexed channels – it would seem to be an ideal candidate for mapping third generation wireless application layer multiplexing on to third generation wireless physical layer multiplexing. Why after all should wireless be different from wireline? The answer is that wireless is different from wireline because bit error rates are generally much higher – typically 1 in 10^3 (1 in 1000) against 1 in 10^{10} (1 in 10 billion) or one in 10^{11} (1 in 100 billion!) in wireline. You could improve wireless bit error rates to something approaching wireline bit error rates by increasing network density but the capital and running costs would be completely unsustainable.

Bit error rates can also be reduced by exploiting latency – send again protocols can be (and are) used to error check data but they introduce variable delay, forward error correction protocols can be (and are) used but absorb bandwidth and power. Using latency to reduce bit error rate also compromises our ability to deliver deterministic traffic.

Determinism is the ability to provide an end to end guarantee of delay and delay variation – it is the single most importance performance differentiator when we come to deliver non-voice products over a wireless or wireline network. Our problem with wireless is that not only do we have a higher bit error rate, it is also more variable than wireline – the user data throughput of wireless ATM is therefore determined by the changing state of the radio channel **not** the changing needs of the user.

The solution is to put in an additional mediation layer to average out, ie reduce, this radio channel induced variation –welcome back the 'traffic codes'.

We have said that one way in which we can influence the bit error rate on the channel is to improve the link budget (for example by increasing network density). An alternative way in which we can influence the bit error rate is to change the spreading ratio between the user information rate and the spreading code rate – the bigger the ratio the higher the coding gain, the better the link budget the lower the error rate. Increasing the spreading ratio can either be achieved by increasing the length of the long code (which increases the RF bandwidth used and RF and processor power budget) and/or decreasing the traffic stream bit rate. Either way, error rate can be held at a low and stable level with either the traffic rate varying or the RF required bandwidth varying over time. For the user, the last option is best in that he has access to a pre-determined and/or pre-negotiated bit rate and a constant and low bit error rate. However, remember that the user's application may not require a constant bit rate, indeed may require a constantly changing bit rate – let's call it the user's 'application rate'. Variation in the application rate can be accommodated by using multiple slots per frame. In this respect TD-CDMA is actually more flexible than W-CDMA in that it retains time division multiplexing in the physical (air interface) layer and can therefore more easily accommodate variations in user application rate (while still maintaining a constant low bit error rate).

DECT and other digital cordless air interfaces such as PHS do therefore have a future as interfaces optimised for the delivery of voice **and** non-voice products over local area wireless networks. Bandwidth on demand can be delivered through multi-slotting to provide the ability to respond to the constantly changing 'application rate' needs of the user. Traffic coding can then be added as a mediation device to provide discrimination between traffic types per user and potentially reduce or average out the variability of bit error rate inherent in the radio channel. At this point, DECT or PHS in effect become TD-CDMA. The disadvantage when compared to W-CDMA is the localised coverage (range limitation). The advantage is better discrimination – the ability to deliver mixed traffic and better determinism – the ability to deliver end to end latency or 'quality of service' guarantees irrespective of the radio channel condition – the benefits of combining CDMA **and** time division multiplexing in the physical access protocol.

There is therefore a readily understandable route map for the migration of DECT (and potentially PHS) to TD-CDMA. There is a readily understandable route map for the migration of GSM, IS136 and CDMA to W-CDMA or Wideband CdmaOne. But where will TETRA go?

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