Digital Wireless—*Regulation and Control Free?*

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Imagine for a moment that we had arrived at our present state of technological prowess without the discovery and implementation of wireless systems. Improbable and impossible, I know, but bear with me and also imagine that we had simultaneously missed out on the feast of the analog and copper era and had jumped straight to optical line systems entirely operating in digital mode. What a vastly different world it would be with near infinite bandwidth connecting every fixed node in our networks. A world where people never asked the question; why do people want bandwidth and what will they do with it? But also, a world without any form of mobility.

Now let us fast forward a few years to when radio propagation systems and the potential for wireless working is suddenly discovered. What would we see as the potential and what would we do? Would we immediately conceive of static, dumb, power hungry, interference prone, and "heavy metal" units offering limited bandwidth? I think not. For sure we would not be thinking AM and FM, with channels and bands. Most likely we would be looking to achieve signal orthogonality through timing and coding. In short, spread spectrum formats might well be our starting point combined with smart beam-forming antennas, intelligent signal timing and code allocation, and active power control sympathetically combined to maximum throughputs.

One of our first jobs would be to postulate potential applications and then to look at the propagation and information capacity characteristics of various frequency (or wavelength) ranges. No doubt, Bluetooth, WiFi, WiMax, PMR, cellphone, and broadcast-like services would be envisaged reasonably quickly and we would set about notionally designing suitable systems. We would most likely also come up with all the network types and forms of networking we enjoy today. At this point what we would not be doing is thinking narrow band, with military, emergency services, police, civil, and broadcast strictly grouped and confined in frequency space. But we might come up with some vague categorizations related to propagation properties, transmission range, and potential throughput roughly related to the low-frequency, middle-frequency, high-frequency, very-high-frequency, ultra-high-frequency, and super-high-frequency categories used today.

Chances are that we would also move to a very few coding and modulation schemes that would allow applications to simultaneously, and maximally, operate in the same frequency space without interference or practical limitation. Crucially, we might also look at minimizing the transition between our optical fiber last mile and core network signal formats and protocols. I am also sure that from the outset, we would recognize the potential of our microprocessors for the dynamic formatting of signals and the management of spectrum use.

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For sure, one big outcome compared to today would be an immediate throughput, adaptability, and utility dwarfing all our efforts to date.

One side-effect of a world saturated by optical fiber would most likely point our thinking in the direction of small cell sites for almost everything—cells in the home, office, shop, street, and so on. So overall, we might envisage the development of wireless systems from small to big sites. That is entirely in the opposite direction of what we have actually seen happen over the past 100-plus years with the migration from dumb, big, "heavy metal" wireless to the small, intelligent, and agile WiFi of today.

And so, back to reality. We do not have a clean sheet of paper; we have a long history of analog systems with established channels and bands allocated across the spectrum up to 30 GHz or so. The pictures depicting these allocations give the impression that the spectrum is crowded and there is no space. The reality is that in the most dense of wireless cities (e.g., Chicago), spectrum use (at < 30 GHz) is less than 17%, while in the 30–3000 GHz space, it is much less than 1%. Even in the major growth areas such as 3G in the United Kingdom, it is not unusual to find occupancies of less than 30% for a major portion of the time. In the military arena, loadings are even less as they have bands allocated on a need basis without any financial or competitive pressure on use and the sharing of this frequency space is a rarity.

Roughly speaking, we have our wireless past well charted: we know exactly where we are and we know what is possible, and we do a have fragmented vision of where we are headed. The big problem is the clutter of our past. The spectrum is strewn with all manner of systems based on technologies that go back as far as the 1915–1920 era. And it is fair to say that a good percentage of the wireless engineering populace remains somewhat skeptical of the future vision and technological population. Why? The older engineers and theorists see the demise of those with a full understanding of Maxwell's equations and the subtleties of interference and intermodulation's being overtaken by a rise of those entirely focused on protocols and economic issues. Not surprisingly, then, progress is being absolutely driven by economic issues and a perceived need to exploit this God-given spectrum.

So what's hot: Going mobile, wireless, and digital for everything; freeing up spectrum for new applications; finding ways of turning spectrum into money for governments and companies; band sharing; auctions; real-time allocations and charging; new applications and services migrating from the old world to the new as soon as possible. Prospecting and license-free operation using SS and ultrawide bandwidth above 30 GHz for office, home, PCB card, intrarack, and chip-to-chip applications. Lightweight regulation and monitoring.

And what's not: Fixed services; analog anything; banded and channelized allocations; spectrum hogging; old applications and services; and anything that blocks or slows down the march of progress to the new. Heavyweight regulation and monitoring.

Somewhat ironically in this context, consumer and corporate spending and change seems to almost synchronize with the sun spot cycle of 11 years. Take the migration from big analog TVs using cathode-ray tubes to the digital plasma and liquid crystal display replacements, for example. With the mean time between failure of five to seven years, coupled with the three- to fivefold early adopter penalty of prices, the market steady-state naturally sees rate of adoption curves exceeding 90% of the population in less than nine years, with more or less 100% take up by year 12. Similar characteristics are also exhibited by commercial and emergency users, with the military, for obvious reasons, very often significantly slower.

So today we are in a migratory phase with cellular mobile, home, and office WiFi in the vanguard of developments, while broadcast radio and TV are somewhat behind with total digitization planned for 2011/2012 in many countries. What the world is really struggling with is the migration from all the old analog-band allocations to the new digital utility approach. Roughly speaking, old analog bands below 30 GHz are systematically being cleared and repurposed—from broadcast to digital mobile applications, for example—but with a consequence that the full capabilities of spread spectrum and signal agility are not being realized. Above 30 GHz, brave, full-on developments are under way to fully exploit what the new digital technologies can offer.

So how is it all going to look in 20 years time? I reckon a few analog systems will still be around, but digital will have largely taken over, and fiber in local loop will have been augmented with wireless drops. In short, wireless will have taken over from wired working, and connectivity on the move will be as common and natural as a cup of coffee. However, it will be in the arena of transparent connectivity that really interesting things will have happened with the simultaneous concatenation of multiple different fixed and mobile links driven by software to deliver the best connection possible at any given time.

We might now ask: what about the role of government and regulators in this new world? Perhaps even more pertinent: will they actually have a role? If they do, it will surely be far removed from that generated by, and experienced through, the analog past and the partially digital present. My guess is that they will only be required to set a broad operating framework for national and international working, while industry and the user communities will be increasingly expected to just get on and solve any real problems that crop up. This then might be the ultimate freedom realized by a technology development line that makes any other outcome very difficult if not impossible. ■

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