



## TECHNOLOGY TRENDS

### SOFTWARE-DEFINED RADIO: Softly does it

**Software-defined radio is helping operators to maximise their investments in multiple mobile standards and base stations. But the biggest benefit, efficient use of precious spectrum resources, is yet to come. By ROY RUBENSTEIN**

A quiet revolution is taking place: Software-defined radio (SDR) promises to prolong the life of cellular base stations while simplifying smartphone design. The biggest breakthrough is still to come: Mobile operators' own exclusive bands are fast becoming choked with data, and SDR will help enable new ways to open up spectrum. But that is a decade away.

"Software-defined radio is an elusive term," says Tod Sizer, a director and leader of Alcatel-Lucent Bell Labs' wireless domain. "It's the ability to modify a radio to perform differently, to improve performance and be used for more than one purpose".

Since the advent of GSM, most of a radio's functions—whether a handset or a base station—have been software-based, says Jan Färjh, vice president and head of Ericsson Research. Designers must trade a radio's flexibility with the resulting processing performance, power consumption and cost. They must also determine whether to implement functions using a fixed, custom-designed chip or more flexible hardware such as digital signal processors and field programmable gate arrays (FPGA). The underlying trend is clear. "There has been a shift to more flexible designs in software," says Färjh.

There are good reasons for this. "Handsets are changing every year, whereas with base stations it is worse, with operators wanting them deployed for decades," says Liesbet Van der Perre, scientific director, wireless research at IMEC, the Belgium-based microelectronics research centre. With SDR, a deployed base station can add a new wireless protocol using a software download only. Such flexible designs deliver significant capital and operational cost advantages, says Van der Perre, while shortening time-to-market and new service introductions.

SDR base-station designs are being adopted by all the cellular equipment makers. Operators as far back as 2004 were upgrading their GSM networks to EDGE using software only, while more recently high-speed packet access (HSPA) download and upload technologies using software have been added to 3G networks. Last month at Mobile World Congress ZTE announced it is working with Hong Kong operator CSL New World Mobility (CSLNWM) to build an HSPA+ network based on SDR technology.

Now equipment makers are extending the idea such that the same base station can support multiple wireless standards. "With SDR multi-standard base stations an operator can maintain existing radio technology as long as needed before migrating via a software update once conditions are right, such as [once] sufficient terminal penetration [occurs]," says Zhongrong Liu, head of radio network technology strategy at T-Mobile International. The same platform can also share the operator's spectrum between radio technologies. "It allows the stepwise reduction of spectrum for the old technology while increasing the spectrum for the new," says Liu.

Nokia Siemens Networks' latest Flexi multimode base station supports three generations of wireless standards and their evolutionary offshoots concurrently: GSM and EDGE, WCDMA and HSPA, and LTE. "There are volume [manufacturing] benefits running multiple technologies from the one platform," says Kai Sahala, head of strategic solution sales in radio access at Nokia Siemens Networks.

SDR is also playing an important role in what Alcatel-Lucent calls the 2G renovation market. Operators now expect to keep GSM until at least 2018, and they are replacing legacy base stations with smaller, lower power, software-defined platforms. “Operators are ensuring [that] the investment [in new base stations for 2G] also support 3G and LTE,” says André Mechaly, marketing & strategy for Alcatel-Lucent’s wireless networks division.

US equipment maker Vanu says it has taken software radio a step further. While SDR uses software-defined parameters executed on digital signal processors and FPGAs, Vanu’s radio functions are written in software executed on Intel microprocessors. “None of these [SDR] elements have the flexibility of a full software solution,” say Steve Muir, CTO at Vanu.

Using general-purpose processors enables wireless to also benefit from software tools and hardware developments driven by the IT industry. Vanu’s base station implements cdma2000 and GSM. “To a base station running GSM, CDMA can be added for roaming users,” says Muir, and by serving more than one wireless standard that will increase an operator’s revenues, he says. Moreover, the resources given to each standard—such as the channels per sector—can be adapted based on user demand.

Vanu’s latest MultiRAN product embraces the idea of virtualised base stations by implementing several radio networks on common hardware. Each logical base station can be customised—one may be GSM only while a second may have EDGE—with their own resource management and security. MultiRAN is aimed at emerging markets such as India, where mobile operators can benefit from sharing infrastructure, and will be trialled this year.

Mobile handsets are also embracing SDR, but for different reasons. Handsets must cram ever more radios to support protocols such as 2G and 3G cellular, wireless LAN as well as mobile TV, GPS and Bluetooth. Six or more radios per handset are now common, says IMEC.

Sandbridge Technologies develops handset chips that implement several radios in software. “An OEM with two or three radios needs to build a new chip; we only have to change the chip’s software load,” says John Glossner, the company’s CTO and co-founder. This has significant development cost benefits while shortening development time, claims Glossner. “Our belief is that software baseband will be a requirement.” At Mobile World Congress, Sandbridge announced it had partnered with Samsung to develop LTE handsets using its SDR chip.

Nokia agrees that SDR will be increasingly used in handsets, but gradually. “It doesn’t solve all the radio implementation problems,” says Petteri Alinikula, Helsinki Laboratory director, Nokia Research Center. For a start, while the baseband processing may be capable of implementing several radios simultaneously, there needs to be distinct radio frequency circuitry to collect the individual radio signals for processing, he says.

There also needs to be deep analysis of the impact of reconfiguration on the design’s cost and power consumption. “This is an extremely complicated equation to analyse,” says Timo Ali-Vehmas, Nokia’s vice president, compatibility & industry collaboration. What’s more, new requirements are always emerging for the leading handset designs and SDR may not be the optimum solution. “SDR is one element in a toolbox. It is not black and white,” says Ali-Vehmas.

Despite such challenges, SDR is already a deployed technology in mobile operators’ networks. Advocates say that is an important precursor to the advent of cognitive radio that promises better use of radio spectrum. “SDR is the underlying implementation technology to enable cognitive radio,” says John Chapin, chair of industry body The SDR Forum.

An SDR radio can adapt but must be told to do so first. A cognitive radio is smart enough to decide itself: it senses the spectrum, and using its understanding of the user’s habits and goals decides the best air interface and spectrum to use.

Cognitive radio is already used within femtocells, to sense their environment and ensure they don’t interfere with 3G cellular macrocells or nearby femtocells. The femtocell listens and works out such issues as the operating frequencies, spreading codes and power levels. “There is a set policy that you can interfere but only to a certain [power] threshold,” says Will Franks, CTO of femtocell maker Ubiquisys. “The idea is that you want the femtocell to cover a residence but not beyond it. In an office environment it is even more complicated.”

A key driver behind the interest in cognitive radio is the concept of decreasing regulation on spectrum to improve its efficient

usage, says Ericsson's Färjh: "It is not used efficiently by those that have it."

UK regulator Ofcom is investigating the merits of cognitive radio. "There is a lot of interest from large companies," says professor William Webb, head of R&D at Ofcom. Ofcom's interest, like the FCC, concerns spectrum associated with the switchover from analogue to digital TV. Of the 350 MHz of spectrum currently used in the UK for TV services, 120 MHz will be auctioned and the rest used for digital services. Unlike with cellular services, a digital licence is issued per transmitter site, each using its own frequency that is reused outside the range of the first transmitter. This results in segments—white spaces—where there are gaps in the spectrum. Using cognitive radio, a device can sense the spectrum and access a database to check on the local transmitters and use the white spaces without interfering with primary digital TV broadcasters.

Ofcom issued a consultation document in February and will decide its next step—likely to be co-ordinating the initiative with the rest of Europe—once it assesses the report responses. The US is set to launch the first white spaces services in June, to coincide with digital switchover, following a lengthy process of debate over whether such spectrum use would interfere with existing broadcast services (*Total Telecom*, April 2008, p.16).

According to Bell Lab's Sizer there is much scope to improve the amount of data carried over the current spectrum using techniques such as smart antennas and advanced modulation techniques. "Today's 3G achieves 0.5 bits per second per Hertz and this is expected to reach 10 or 20 bits per second per Hertz in years to come."

But the consensus is that radio spectrum will eventually become scarce even for operators. "The increase in data exchanged [wirelessly] will edge us into conflict in the spectrum," says Van der Perre. And if mobile operators see little reason to pursue cognitive radio now, they will once they start to run out of spectrum, says Sizer.

But T-Mobile's Liu says commercial exploitation of cognitive radio is not expected for at least the next 8–10 years. What's more Ofcom's Webb is circumspect about the impact of cognitive radio. "I don't believe it will lead to a revolution in the way we use spectrum," he says. n

### **Defining Sdr and Cognitive Radio**

The IEEE and The SDR Forum have a rigorous definition for software-defined radio: "It's a radio where some, or all, of the physical layer functions are software defined," says Manuel Uhm, director, wireless communications at FPGA company, Xilinx.

There is a five-tier radio classification scheme. Tier 0 refers to a rigid hardware radio, while Tier 4 is a fully flexible radio that has a programmable radio frequency that can capture a wide range of radio signals, and programmable baseband hardware that processes the sampled radio signal. The SDR definition given by Uhm refers to a Tier 2 radio: "It refers to the radio's baseband processing functions but doesn't mention the RF."

The SDR Forum splits cognitive radio into two categories: self configuring/self optimising networks and dynamic spectrum access (DSA). A femtocell is an example of a self-organising device that uses cognitive radio techniques. LTE base stations will also embrace such techniques to aid radio planning as new cell sites are added.

Dynamic spectrum access can also be split into two: co-operative and non co-operative. An example of co-operative DSA is when "multiple entities share a channel and agree methods that protect against interference", says Chapin at The SDR Forum. With non co-operative DSA, an unlicensed user, without permission of the primary user, listens and accesses a database to determine that the channel is available before transmitting its service. The FCC has approved such a scheme using a broadcaster's TV channels as long as the user sticks to the white spaces and avoids interfering with the primary user.