The View Ahead: Technology Opportunities

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It is an unfortunate fact that spectrum policy often instigates innovation and technical opportunities, rather than the converse, as we would wish. Spectrum policy that is driven by existing products will inherently support the continuity of these products, rather than innovation.

The ecosystem that evolves in spectrum-dependent innovation will closely mirror the ecosystem of spectrum availability. Technology opportunities arise not only from the inherent sciences driving wireless communications, but also from the opportunities provided by spectrum policy. Today, innovation occurs in two extreme domains, the long-term exclusive licensed spectrum, and the unlicensed spectrum. The unlicensed spectrum has seen particular innovation, with new generations of wireless LANs appearing almost annually. A simple principle might be that flexible spectrum availability is an incentive and motivator for innovation.

There are a number of avenues such innovation could take. These include:

Flexible Mixing of Licensed and Unlicensed Spectrum and Technologies. Some form of spectrum sharing is inevitable. It is likely that the resulting model will inherit features from the two competing models of today (exclusively licensed spectrum, and unlicensed spectrum). Each provides unique features, and is enabling for certain investment and operational models. It would be unreasonable to assume that the vast pool of sharable spectrum would be "locked" into sole use through either model.

Fusion of WiFi and Cellular. Wi-Fi is the dominant technology for unlicensed, local communications. LTE is the dominating cellular standard. However, LTE is being increasingly applied to local applications, such as in Femtocells, and Wi-Fi has become the major media for cellular smartphone Internet access. WiFi has advantages in its ability to operate independently of infrastructure and high volume/low cost. LTE has advantages in its ability to provide handover and high QOS.

A reasonable prospect is that flexible spectrum policies, such as those proposed by PCAST, could breakdown the "partition" between licensed technologies (LTE/5G) and unlicensed Wi-Fi. Access points could offer LTE/5G services on licensed or

unlicensed spectrum, depending on wholesale arrangements, and the economy of scale could enable the future of both of the candidate technologies to create "best of breed" solutions.
Flexibility in spectrum licensing arrangements could enable fundamental innovation in both the market and technology opportunities in local service provision. This would imply that services would be most optimal if they could serve both

Automated Co-Existence Management. Most of the cognitive radio discussion has revolved around methods of frequency selection. However, it is clear that frequency isolation is not sufficient to ensure spectrum coexistence, as is seen in the process of resolving interference issues arising from properly isolated spectrum proposed by LightSquared and M2Z. In a dynamic sharing environment, or even a flexible use spectrum policy (such as proposed by the Spectrum Policy Task Report), then the technology will have to inherently address the adjacent band coexistence impacts

Tunable Filters. While military systems have generally provided tunable RF devices, civil spectrum management practices have resulted in little benefit to civil systems, so these applications have generally relied on massively lower cost fixed RF filters. Full exploitation of the spectrum policies proposed in the PCAST report will require the availability of tunable filters in civil devices that want high confidence of accessing spectrum in congested bands. This is not just a consequence of spectrum sharing, but is probably highly advantageous to existing cellular architectures, as the proliferation of frequencies and diplexer arrangements in world-wide LTE deployments is way beyond the capacity of fixed filter solutions. Also, the timeline for regulatory solutions is clearly not supportive to rapid or deterministic resolution of these issues. Today, these issues arise late in the deployment process.

Closed Loop Interference Management. All of the current approaches to spectrum interference avoidance are based on predicting propagation, and ensuring separation (in frequency and space) sufficient to reduce the probability of interference to an acceptable level. Unfortunately, that means that most of the time, the separation is far in excess of what is needed (on the order to 10's of times in space), resulting in massive losses in the potential utility of the spectrum (100's of times). Even the TVWS or PCAST proposed approach are based on high-confidence levels of interference prediction. Dynamic Spectrum Access is somewhat better, but can not estimate propagation from the victim transmitter to the victim receiver, or between the sharing transmitter and victim receiver.

The optimal use of spatially shared spectrum is through closed loop interference management, between all of the heterogeneous devices that share the spectrum. LTE-A has much of this technology within an individual, homogeneous, LTE-A network, but this technology will need to be generalized to address the full range of communications and sensing technologies.

The incentives for al spectrum users to do this are the same as for LTE-A. For example, the PCAST report proposes to license shared spectrum based on the opportunity cost of the license. Reduction in the interference exclusion zone would reduce the extent, and therefore the likely cost, of a license. Users would thus have an incentive to reduce the exclusion zone by cooperation, rather than precluding operation over the widest possible area.