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802.11n delivers developing ecosystem

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The rollout of 802.11n networks has a unique impact on the dynamics of the market and, ultimately, the users of the next generation of wireless-LAN technologies. While 802.11n delivers the higher speed and improved range desired, the cost and complexity of enabling an existing network to handle 802.11n has become somewhat of a barrier.

This technology offers substantial benefits over previous wireless standards, with speeds up to five times faster than traditional WLANs, greater range and improved reliability to support high-performance applications, such as high-definition video, high-resolution imaging and voice-over-WLAN. As such, it is important to take a look at how the ecosystem is developing for this advanced mobility. How is this latest in a series of Wi-Fi standards affecting the market dynamics?

The 802.11 chip set vendors, such as Broadcom and Atheros, have played a crucial role in the ecosystem. These fabless semiconductor companies obtain intellectual-property (IP) designs for each generation of 802.11, either through internal development or by acquisition from a specialized IP developer, then map this IP to a particular foundry through which the actual manufacturing of the silicon is outsourced. Finally, they sell their chips to OEMs that are making access points, gateways, PC cards and the like.

Although standalone 802.11n access points and end devices are now appearing in the enterprise and consumer segments, what is most interesting is the developing application of complementary technologies. The market is seeing a dynamic and highly interdependent relationship among multiple technologies. By considering the interdependent nature of technology evolution, we can identify the types of interaction between technology roles as "paths of access."

As a result, technologies that can bring broadband access to the enterprise or home are now looking to offer transparent migration in the building coverage provided by 802.11n. This could include combinations of DSL/802.11n, WiMax/802.11n, LTE/802.11n, Docsis/802.11n and so on.

It is important to keep in mind that each wireless technology offers different mobility, speed and cost characteristics. The 802.11n option will always have the best cost and performance characteristics, while WiMax may have true wide-area reach. Thus, a solution that offers a combination of WiMax to get to the building and 802.11n for the interior networks positions itself as a viable and much-needed one. In the future, the application running on the handheld or laptop will make the best choice between 802.11n and WiMax.

To better understand this dynamic, it is important that the so-called "Core 3" paradigm, or critical market requirements in the wireless arena, be identified.

The basis of the Core 3 paradigm lies in the need for products that silicon companies are designing to specifically meet the demands of various market segments. These include the handheld segments, service provider customer premises equipment (CPE) and high-end home gateways and routers.

The critical issues in the handheld segment are power consumption and price. This market is willing to compromise performance to maximize both of the other constraints. Users have become accustomed to the fact that handheld devices will work not only for hours, but for days, on a single charge. The second issue, price, is paramount, as the OEMs making the handheld must keep the bill of materials as low as possible to secure a retail price that people will pay in a market with short product lifetimes and rapid upgrade cycles.

When looking at the recent introduction of Apple's iPhone, the device was touching the top end of the price ceiling. In the world of multiple-input, multiple-output (MIMO) used in 802.11n, this likely translates into a 1x1 configuration (SISO).

It is especially challenging to maximize the Core 3 in service provider CPE equipment, since the segment must balance all three components: price, performance and power consumption. Price is still very important, of course, but the demands of in-building use make performance more of a requirement for CPE devices. Power consumption might not seem like a critical issue until it is interpreted as heat generation. OEMs do not want to put fans into CPE devices due to cost, size and noise constraints. In the world of MIMO, this balance might translate into a 2x2 or 2x3 configuration.

High-end home gateway/routers are facing new uses, such as high-definition streaming video. As such, it is probably the easiest segment with respect to the Core 3 decision process, but the hardest with respect to technology performance. Performance is king in this segment. Achieving maximum throughput and maximum link distance is the goal. In terms of MIMO, this translates into a 4x4 configuration.

As these examples show, 802.11n must possess a high degree of segment specialization due to the specific configuration needs of different target markets. The MAC layer, which serves as the coordinator or traffic cop for wireless packets, must be interoperable among all the configurations of .11n. Thus, customization for different segments doesn't affect its features or architecture significantly. The PHY, or lowest level of the OSI network model, deals primarily with the transmission of the raw bit streams over the physical transport medium. In the case of wireless LANs, the transport medium is free space. The PHY defines parameters such as data rates, modulation method, signaling parameters, transmitter/receiver synchronization, etc. Within an actual radio implementation, the PHY corresponds to the RF radio front end and the baseband signal-processing sections.

The capabilities and functions of the PHY vary greatly with the different configurations of 802.11n. The exact architecture selected for a configuration determines where it will fall within the Core 3 trade-off space. Specifically for 802.11n, which uses MIMO, this means that the MIMO decoder and other blocks that drive the MIMO configuration must be customized to the various configurations: 1x1, 2x2, 4x4, etc. As an example, the 1x1 configuration used for handhelds would need a PHY architecture highly optimized for low power consumption. The existing 802.11 chip set vendors will thus develop a family of .11n chip sets falling at various places in the Core 3 space.

In reality, the concept of distinct market segments and well-defined ideal configurations may be an oversimplification in the evolving 802.11n ecosystem. The .11n variant has far more modes of operations than previous 802.11 generations. As compared with the four rates of 802.11b and the eight rates introduced in .11g, .11n supports hundreds of data rates. In an ideal world where cost and power consumption was not an issue, all .11n nodes would support all the modes of operation and the maximum data rate of 600 Mbits/second. This is far from reality, however.

In addition to the choice of spatial streams discussed above, two other configuration choices have a dramatic impact on cost and power consumption: the selection of 20-MHz or 40-MHz channels and of single-band vs. dual-band. Further, some applications may have asymmetric data rates and thus make an .11n node with asymmetric transmit-and-receive capabilities an attractive option.

While it is likely that different manufacturers will use different configurations in the same application, it is clear that a tremendous diversity of usage needs is creating a market for a diversity of .11n configurations. In prior generations of 802.11 WLANs with far fewer optional modes, the chip sets basically consisted of four possibilities combining choices of low power vs. high performance and single-band vs. dual-band. This market was well served by the relatively few chip set combinations available from the likes of Broadcom and Atheros.

With so much more potential for trading off cost, power and performance in 802.11n, it is unclear whether the supposed sweet-spot configurations offered by each chip set vendor are really well balanced and suited for most or all applications, or whether they are merely middle-of-the-road compromises providing workable solutions for many applications, but ideal solutions to few.

The alternative to the chip set model of the previous generations of Wi-Fi is the model of licensable cores that can be configured utilizing all the degrees of freedom that .11n provides. Many system designers who simply chose to use discrete 802.11 chip sets in past generations of devices are now considering integrating a custom .11n core within a system-on-chip (SoC). The choice of channel bandwidth and number of data streams has a large impact not only on the digital baseband gate count and power consumption, but also on the cost and power consumption of the analog and RF circuitry. The days of "two (or three) sizes fit all" have likely come to an end with the introduction of 802.11n.

In addition to the ecosystem model served by the traditional 802.11 chip set companies, a new model is arising to meet these new demands. This alternate model is based upon the SoC paradigm, where a new set of fabless semiconductor companies design single-chip solutions for particular market segments, including complementary technologies with architectures highly optimized for the exact segment the device is to serve. In this ecosystem, the SoC companies obtain

802.11n IP directly from specialized IP developers and subsequently sell the SoC chips to OEMs and consumer device manufacturers. In the end, consumers benefit from having a much wider range of product offerings with superb cost, performance and power characteristics.

About the author

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