ATHEROS COMMUNICATIONS, INC. **TECHNICAL BACKGROUNDER**

AR7100 Wireless NPU Technology Backgrounder:

Network Processor Strategy for Maximizing 802.11n Wireless LAN Performance

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ATHEROS® COMMUNICATIONS

Introduction

Because 802.11n-compliant wireless LANs (WLANs) sustain much higher throughput than previous-generation 802.11g and 802.11a/g networks, the new technology places significantly higher demands on a wireless access point (AP)/router's network processor. A high-performance network processing unit (NPU) is one way to meet these new demands, but many such NPUs are too expensive for consumer WLAN applications.

Moreover, even expensive NPUs do not always handle the necessary tasks efficiently enough to deliver the full performance of 802.11n networks. Nor do these NPUs provide the high-speed interfaces required to support multimedia applications-the ideal applications for 802.11n's high-throughput capabilities. Integrating the necessary processing and interface speeds in a cost-effective NPU is vital to enable the growth of 802.11n-based multimedia applications in the market.

The IEEE's draft 802.11n specification includes the use of multiple transmitters and receivers (2x2, 3x3 or 4x4 transmitters x receivers, for example), spatial streams and other features that increase a WLAN system's potential throughput, such as frame aggregation, spatial multiplexing and 40-MHz operation. These features provide maximum physical data rates as high as 600 Mbps per link, compared to 108 Mbps for previous-generation 802.11g and 802.11a WLANs.

For home and small business users, 802.11n enables a revolutionary transformation: triple-play gateways and SOHO APs/routers offering seamless support for video, voice, and data interactions across all home applications. For example, users of these 802.11n WLANs will be able to transmit HDTV streams around the home or office while simultaneously carrying voice traffic for VoIP handsets, supporting Internet data-centric applications, and enabling increasingly demanding multi-player game-console communications.

802.11n's high level of performance also offers a crucial advantage for enterprise IT managers, whose goal is to provide reliable, high-performance, location-independent connectivity. Today's enterprise WLANs must support secure transmission of mission-critical data, and increasingly data that includes latency/fidelity-sensitive VoIP communications.

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A New Category of Solutions: Wireless NPUs

Atheros Communications determined that by using an architecture optimized for WLAN - a *Wireless* NPU (WNPU)--can provide sufficient performance and features at a reasonable cost. Using such a WNPU makes it possible to develop highly cost-effective wireless products, including general-purpose WLAN APs and routers that meet the needs of new-generation home, SOHO and enterprise applications.

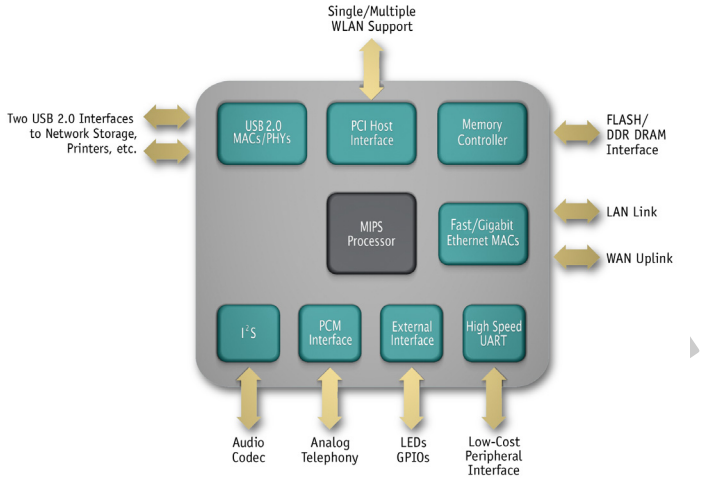
Atheros has implemented the necessary capabilities in the AR7100 family of WNPUs. In addition to features such as a high-speed processor core and high-bandwidth interfaces, these devices provide an advantageous balance of memory resources that significantly improve an application's overall throughput-an improvement that fully supports the performance available from 802.11n.

This technology backgrounder describes the AR7100 WNPU family and the key features that enable full-speed 802.11n baseband processing. Also provided is an overview of wireless products that can leverage the available throughput.

Network Processing Units for 802.11n WLANs

The Atheros AR7100 WNPU family comprises three silicon solutions to address specific end-product tiers. The two fastest AR7100 family members include 10/100/1000 Ethernet interfaces. The other WNPU in the family is for less demanding applications that require only 10/100 Ethernet. All of Atheros' WNPUs are software compatible and thus support a common software code base, providing a hardware upgrade path and allowing efficient code migration to multiple platforms.

Figure 1. **AR7100 Block Diagram**



At the heart of these devices is a MIPS32® 24K® processor-the processor of choice for many types of high-performance networking applications. The three members of the AR7100 family provide the following processor speeds, WLAN configurations and Ethernet speeds:

- AR7130 WNPU
  - 300 MHz (425+ Dhrystone MIPS)
  - Designed for value-tier 2x2 MIMO 802.11n AP/routers operating in the 2.4-GHz band
  - 10/100 Fast Ethernet interface support
- AR7141 WNPU
  - 400 MHz (575+ Dhrystone MIPS)
  - Designed for high-performance 3x3 MIMO 802.11n AP/routers operating in either the 2.4- or 5-GHz band
  - 10/100/1000 Gigabit Ethernet interface support
- AR7161 WNPU
  - 600 MHz (850+ Dhrystone MIPS)
  - Designed for the highest performing 3x3 MIMO 802.11n AP/routers with concurrent operation in 2.4- and 5-GHz bands
  - 10/100/1000 Gigabit Ethernet interface support

In addition to Ethernet connectivity, these WNPUs offer several types of interfaces to connect to local media sources and peripherals, such as:

- Dual USB 2.0 ports for wireless network storage and printing
- Pulse-code modulation (PCM) interface for analog and VoIP telephony
- I^2S interface for audio streaming
- PCI 2.3 interface for connections to the WLAN BB/MAC device(s)
- Double-data-rate (DDR) memory interface for high throughput to and from external DRAM

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Boosting NPU Throughput

It is no surprise that memory access speed is one of the most important aspects of NPU performance for 802.11n. But, in this high throughput application, the size of an NPU's instruction cache also has a strong influence on the memory access frequency - and thus the overall system performance.

Microprocessors of all types use on-chip caches for immediate access to recently used instructions or data, thus minimizing the need to wait for somewhat slower transfers from external DRAM. When processors have separate instruction and data caches (as is the case with MIPS processors), the two caches are usually the same size.

For a WNPU, the instruction cache size is critical because the processor mainly performs two tasks: translating Ethernet frames into WLAN frames and vice versa. If the WNPU's instruction cache is big enough to accommodate the code for translations in both directions, the processor normally needs to access external DRAM for instructions only once. Atheros designers determined that the necessary code takes approximately 42 KB of storage, so they implemented a 64-KB instruction cache for AR7100 WNPUs (compared to 32 KB for the data cache).

As a result, an AR7100 WNPU rarely needs to fetch instructions from outside the cache, and the processor can devote its entire external-DRAM bandwidth to data transfers. To eliminate another potential data bottleneck, an AR7100 WNPU implements a fast DRAM interface (in this case, 16- or 32-bit-wide DDR running at 300 or 400 MHz, depending on the device).

Maintaining this throughput is not just a matter of keeping pace with “normal” traffic flows, because 802.11n includes provisions for packet aggregation and selective retransmission. The aggregation process groups many small packets into one big packet. If a bit error occurs in one of the small packets, the sender resends just that one packet. This process is fast and efficient, but it requires a large amount of memory for the reconstruction because the sender must retain many packets until they have been received correctly and possibly reorder them. Thus, 802.11n devices need larger data structures in memory to maximize throughput.

Another memory factor is the ability to support multiple I/O operations in parallel via the WNPU's various ports. The on-chip SRAM in AR7100 WNPUs has 5 ports that enable simultaneous access to and from five sources: the two gigabit Ethernet ports, the PCI port, the USB 2.0 port and the MIPS processor.

Tests show the 300-MHz AR7130 WNPU achieves higher throughput than a competitor's widely used (and more expensive) 400-MHz general-purpose NPU when coupled with the same Atheros WLAN chips--and still had 37 percent processor headroom available for added value functions. The 400- and 600-MHz AR7100 WNPUs ramp performance proportionately.

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Straightforward Application Solutions

Both Intel and Microsoft (among others) are promoting widespread use of dual-band WLANs to maximize network efficiency, availability, and performance-2.4 GHz for data and 5 GHz for multimedia applications. This dual-band approach is especially useful with Microsoft's new Windows Vista™ operating system, which focuses on multimedia capabilities. The 5-GHz band offers much greater bandwidth and lower interference, so it is ideal for multimedia applications ranging from VoIP telephony to HDTV streaming.

For single- or dual-band applications, highly integrated Atheros WLAN solutions combine with the AR7100 WNPUs to implement compact, cost-effective wireless products. The diagrams shown here illustrate three common configurations of Atheros AR7100 WNPUs and WLAN devices along with an Ethernet PHY (for WAN connection) and an Ethernet switching chip for LAN connections.

Figure 2. **AR7100 Applications: Draft 802.11n Single-band AP/Router**

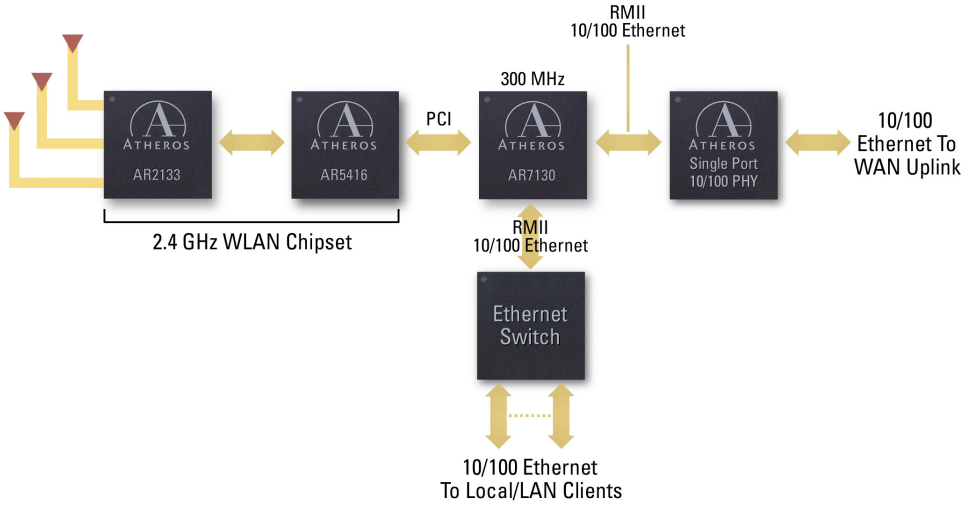

Figure 3. **AR7100 Applications: Multi-Function Draft 802.11n AP/Router**

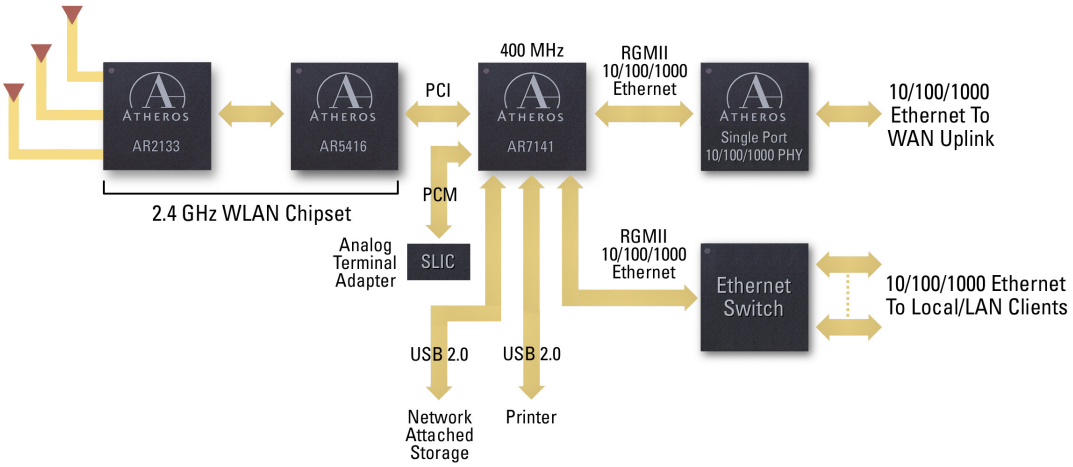

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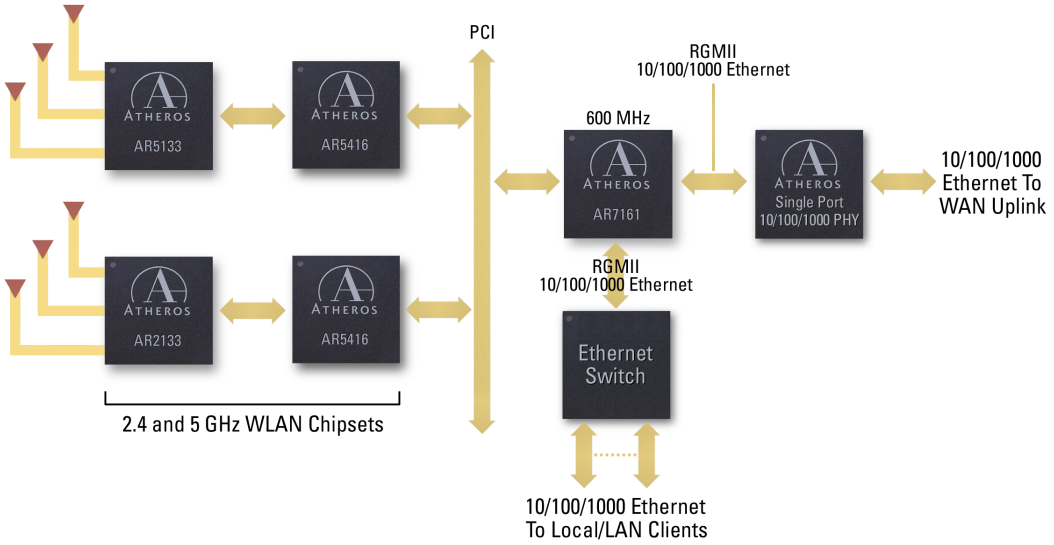
Figure 4. **AR7100 Applications: Dual-Concurrent Draft 802.11n AP/Router**



The WNPU's USB 2.0 ports allow AP/routers to accommodate peripherals such as printers and disk drives, so these resources can be available via the wireless network. Similarly, the WNPU's I2S interface can be used to implement a speakerphone or to play streaming audio. The PCM interface supports telephony applications.

Note that the 2.4/5-GHz dual-concurrent implementation shown here requires only four WLAN chips along with the Atheros 400-MHz AR7141 WNPU. Reference designs are available for all the configurations shown here. Atheros also provides software to implement the basic functionality of these AP/router applications.

Atheros WNPU technology offers a versatile way to expand the range of 802.11n WLAN applications. These applications range from NAS servers that integrate AP functionality to 802.11n AP/routers that include 802.11s mesh capability. With high-performance Atheros WNPUs at price points appropriate to these applications, system developers can create a new world of low-cost wireless products that deliver voice, video and data services via a single, trouble-free network.

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