Tune in: MIMO IP for FPGAs benefits military and commercial radios

An interview with Babak Daneshrad, PhD, Silvus Communication Systems

Editor's note: *Silvus Communication Systems is a company you've probably heard little about in the media. So far, they've flown under the radar, quietly developing Multiple Input/Multiple Output (MIMO) IP and working under DoD Small Business Innovation Research contracts (SBIRs) and a new DARPA contract. But Silvus has some amazing IP – they've cracked the code on tuning Software-Defined Radio (SDR) antennas to take advantage of time, frequency, and space. Using their IP in an FPGA, users can optimize for ultra-high bandwidth data rates, low probability of detection, low power, or small physical size. We conducted a telephone interview with the company's founder, UCLA Professor Babak Daneshrad, who is so easygoing that he insists on being called by his first name. Edited excerpts follow.*

– Chris Ciufo, Editor

DSP: ***Can you briefly describe what Silvus does?***

DANESHRAD: Founded in 2004, Silvus' charter is to deliver breakthrough wireless broadband products for high-speed, high-fidelity applications in both the military and commercial sectors. The company heavily leverages multi-antenna MIMO systems to achieve this objective. After winning a series of SBIR contracts, Silvus was chosen in 2007 as the single performer on the DARPA MNM [Mobile Networked MIMO] program and is currently gearing up to launch its commercial 802.11n-based product (both IP and radio units).

DSP: ***Describe some of the unique technical problems/challenges facing your target customers.***

DANESHRAD: Invariably, our military customers face demands for reliable wideband communications in high scattering, multipath rich environments such as those present in urban canyons. Multi-antenna, MIMO-based systems actually thrive on multipath, and when combined with advanced modulation schemes such as OFDM [Orthogonal Frequency Division Multiplexing], provide an extremely reliable link.

Our commercial 802.11n customers will benefit from an open source IP that provides them with full control of their product roadmap and has been designed to meet superior military requirements. They simply cannot buy a functional 802.11n IP core today.

DSP: ***Your company backgrounder says Silvus is an "SBIR design shop," which points to a strong military intent. How does your technology meet the needs of the warfighter?***

DANESHRAD: In short, our technology improves reliability and guarantees communications under harsh electronic and operational conditions typical of urban warfare, terrestrial mobile operations. Moreover, the versatility afforded by the optimal matching of the multi-antenna spatial processing plus the traditional time and frequency domain signaling result in a radio that is "morphable" to mission and channel conditions. All these elements will go a long way to guaranteeing the best communications at the minimum power consumption for the warfighter.

Our technology will guarantee an "elastic" pipe, thin and long for lifeline long-range communications, fat and short for 100 Mbps links in indoor or urban canyons. This is a departure from the traditional single mode radios that give you a single throughput rate and then go dead when the channel conditions become unfavorable.

DSP: ***What are the pros and cons of multi-antenna processing systems, and can you cite some commercial and/or military examples?***

DANESHRAD: The benefits of multi-antenna processing are substantial, to the extent that all commercial broadband wireless communication systems are incorporating multi-antenna MIMO techniques into their standards (IEEE 802.11n, WiMAX, 3G-LTE cellular, and so on).

Multi-antenna techniques essentially augment the traditional two dimensional time-frequency signaling space into a three dimensional signaling space consisting of time-frequency-space. This augmentation provides the radio with an additional degree of freedom to achieve many objectives, including additional throughput, extended range, improved reliability for the same Tx power, and energy efficiency.

Multi-antenna techniques can also be exploited to extend range and battery consumption. In short, a 4 x 4 [4 transmit and 4 receive antennas] STBC [Space Time Block Coded]-based MIMO system can deliver the same performance as a single antenna system with as much as 15 dB or 31x less power. This simple fact can be exploited to either reduce the transmit power to save power or extend the range of communications.

The cons of multi-antenna techniques stem from the need to have multiple antennas and multiple RF transceiver chains to carry the signals down to baseband.

DSP: ***You've said that the magic occurs when MIMO is coupled with OFDM. But what fundamental technologies need to be "born" … or still must advance further … for your vision to be realized?***

DANESHRAD: None, really. OFDM and MIMO are currently being married together in all broadband commercial wireless systems. For the military market, the challenge is to adapt the system for extremes of jamming, mobility, and communications in urban settings.

DSP: ***Silvus appears to have two product choices: IP cores or actually selling SDR radios using FPGAs. Walk us through your decision process and how each most benefits the market(s).***

DANESHRAD: The complete radio unit – the SDR you referred to – is a fully self-contained radio with the Silvus processing being carried out in the baseband FPGA. It is ideal for networking engineers looking to build a state-of-the-art, mobile, *ad hoc* network with superior performance by leveraging the diverse set of capabilities provided by the Silvus radio.

The IP core is intended for the radio developer looking to augment current radio capabilities with Silvus' multi-antenna MIMO capabilities. In this case, the form factors and the actual FPGAs used might be different, or the RF transceivers may be different. Another benefit of the IP core is for the customer who wants to cost-reduce the solution by taking the MIMO capability into an ASIC.

DSP: ***Please comment on MIMO as part of mesh networks and how this affects certain applications.***

DANESHRAD: The benefits of MIMO easily spill over into the network as well. It enables the concept of SDMA [Space Division Multiple Access]. Moreover, the higher bandwidth and smaller required Tx power will lead to improved frequency reuse and an overall increase in network throughput.

MIMO has the potential to significantly improve mesh networking. With a single radio, the network can decide if a single, low bandwidth long hop or a multiple of short, high bandwidth hops is more appropriate. If the application is speech, for example, the queuing latency in a multihop transmission might be excessive; however, if overall network throughput is to be optimized, then a multihop, high bandwidth scenario is more appropriate.

DSP: ***Clearly, FPGAs and signal processing are at the core (no pun) of your system. What* enhanced *or* next-generation *features do you need in silicon, software, or tools to make your system better, and why?***

DANESHRAD: No new silicon or software features are needed. As semiconductor technology continues to shrink, the sophistication of the algorithms that can be implemented in a MIMO system increases, and MIMO communications will become more affordable.

Inherent in MIMO receivers is a matrix inversion operation that grows in complexity exponentially as the number of antennas increases. More advanced semiconductor process technology will allow larger arrays to be reasonably manufactured.

DSP: ***What does the future hold?***

DANESHRAD: As the sole performer on the MNM Phase 2/3 program, Silvus is well positioned to be an early entrant into the 802.11n IP market and poised to take advantage of the broadband wireless video distribution market. With a small, highly motivated team, Silvus has made tremendous inroads in establishing MIMO as a key element of future military communications. DSP-FPGA.com

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Babak Daneshrad *is chairman and founder of L.A.-based Silvus Communication Systems and Professor of Electrical Engineering at UCLA. Prior to Silvus, Babak served as founder, CEO, CTO, and chairman of Innovics Wireless, Inc., a fabless semiconductor company that developed the first multi-antenna, diversity-enabled, WCDMA-3G mobile terminal ASIC. Babak's research in the areas of MIMO, OFDM, and broadband wireless has been published in many peer-reviewed journals. He holds a PhD in Electrical Engineering from UCLA.*