Server Based Solutions for Self-Organizing Networks

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The evolution of networks across generations of evolving protocols has led to a complex mixture of deployed wireless systems. Development towards 5G and the increasing use of heterogeneous networks (HetNets) to improve coverage with fill-in solutions has created an environment of growing complexity, whose management and resource allocation has become a key issue for network operators.

This paper presents the ideas and initiatives driving self-organizing networks (SONs), a key enabler for effective 5G deployment. The authors look closely at the challenge of a data center-based eNodeB pool in a Cloud RAN (C-RAN) context and present a possible solution based on open standard technologies.

Optimized Spectral Efficiency

In addition to growing network complexity, there is also an alarming shortage of bandwidth in the radio spectrum. The ability to optimize the networks to maximize the spectral efficiency of wireless coverage is key to the future of user bandwidth delivery. Invariably this means rationing spectrum by providing just enough resource for the type of device connected. Developments such as Narrow-band LTE (NB-LTE), for example, will be a key enabling technology for the Internet of Things (IoT). The management and coordination of networks with a mix of these 200kHz bands alongside conventional 1.5MHz to 20MHz bands will soon be the norm.

Adaptation

And it's not just spectral efficiency of mobile communications. As the airwaves become more congested, blocking signals from other sources becomes a prime obstacle to attaining maximum data bandwidth. The ability for a network to adapt to the spectral environment in a coordinated fashion provides a great advantage to maintaining the best service. LTE already includes Channel Quality Indicators (CQIs) for channel allocation within a band, and if a network can be devised which spans multiple bands then these same CQIs could be use at a high level of abstraction to favor the operation of different bands within different locations.

Dynamic Geographic Allocation

Lastly, geographic network demand is seldom static over time. The peak demand during the working day is likely to be concentrated in the commercial districts while an evening profile may be skewed by a sports event in one area or a concert event in another. The network needs to address this temporal shift in demand. Activation of fill-in cells and the direction of network processing resources to the cells experiencing heavy user registration are key for network bandwidth management.

Self-Organizing Networks

Software Defined Networking (SDN) and Network Functions Virtualization (NFV) are initiatives which promise to free the network from the rigid framework of one-off network provision, and which are key enablers for Self-organizing Networks (SONs). This requires the challenging re-imagining of network components and architectures around a central point of intelligence and coordination.

This central point of a Co-operative MultiPoint (CoMP) network finds a natural home in the data center. It is already home to the Evolved Packet Core (EPC) in large networks and is the center for routing and policy management. Adding network management capabilities enables the support of hosting multi-tenant Mobile Virtual Networks (MVNs) and the ability to time-share network resources as part of service contracts.

Co-locating the higher layers of the LTE protocol stack here also provides a much richer source of network management data. This can be used to fuel the intelligence of network organization, for example by providing access to data mining tools and facilitating more predictive network analysis. It's conceivable that using the GPS component of mobile data to anonymously track users would support resource allocation before it is required, such as turning on a fill-in cell as a crowd gathers at a rock concert.

A side benefit is that the data center offers a less challenging environment than most base station locations, reducing the CapEx cost of equipment ruggedization. Advanced cooling and power management technologies in this environment save energy; and providing a single point-of-service access reduces OpEx.

Re-Imagining the Network

There is no unified view of how these network components are to be re-imagined. There are, however, a range of competing ideas, initiatives, and solutions:

- For example, the European Horizon 2020 COHERENT project, of which CommAgility is a participant, is looking to develop a unified programmable control framework for managing heterogeneous networks, (HetNets) which will be key to 5G success.
  - A key initiative is to provide a simplified abstracted network view to support coordinated network resource allocation across all network types. This will lead to interface development to support programmable control and coordination to support new services.
- Working on the signal chain from the air interface to the EPC, the first key element is the Remote Radio Head (RRH). Traditionally the RRH was a single sector radio mounted up the antenna mast supporting a point-to-point link back to the eNodeB located at the base of the mast. Common Public Radio Interface (CPRI) has become the protocol of choice for this link, connected over optical fiber.
  - Extensions to CPRI such as the Open Radio Interface (ORI) have been developed to support the concept of a distributed base station architecture. This technology and others are designed to replace the eNodeB at the mast with a front-haul technology from the data center to the RRH in a so-called Cloud RAN (C-RAN). ORI maintains the latency and delay timing requirements of the digital RF interface required by LTE, while striving to achieve data compression of at least 50% to facilitate more efficient use of the front haul.
  - Newer contenders such as Radio over Ethernet (RoE), IEEE1904.3, are attempting to leverage the lower cost and ubiquitous nature of Ethernet Over Passive Networks (EOPN) to achieve the same result. In deployments where there is no existing dark fiber for use, the limitations of Ethernet may be an attractive compromise.

The evolution of the SDN supports the reconfiguration of these RRHs using Software-defined Radio (SDR) techniques to support multiple bands at multiple bandwidths, thus allowing each RRH to play its part in the HetNet. Where a channel experiences interference, the RRH frequency may be moved. In areas of low usage, the bandwidth of the supported channel can be reduced and that bandwidth re-allocated to a busier cell without creating adjacent channel interference.

RRHs can be turned off and on depending on local demand, being used as sniffer channels to feedback details of the RF environment to improve overall network coverage.

Moving the eNodeB inside the data center allows the support of multiple RRH connections, not just the traditional three-sector model. This Distributed Antenna System (DAS) model brings in multiple RRH connections to the data center, which can then be switched to a high-density eNodeB pool where the wireless data processing can be shared across a central resource.

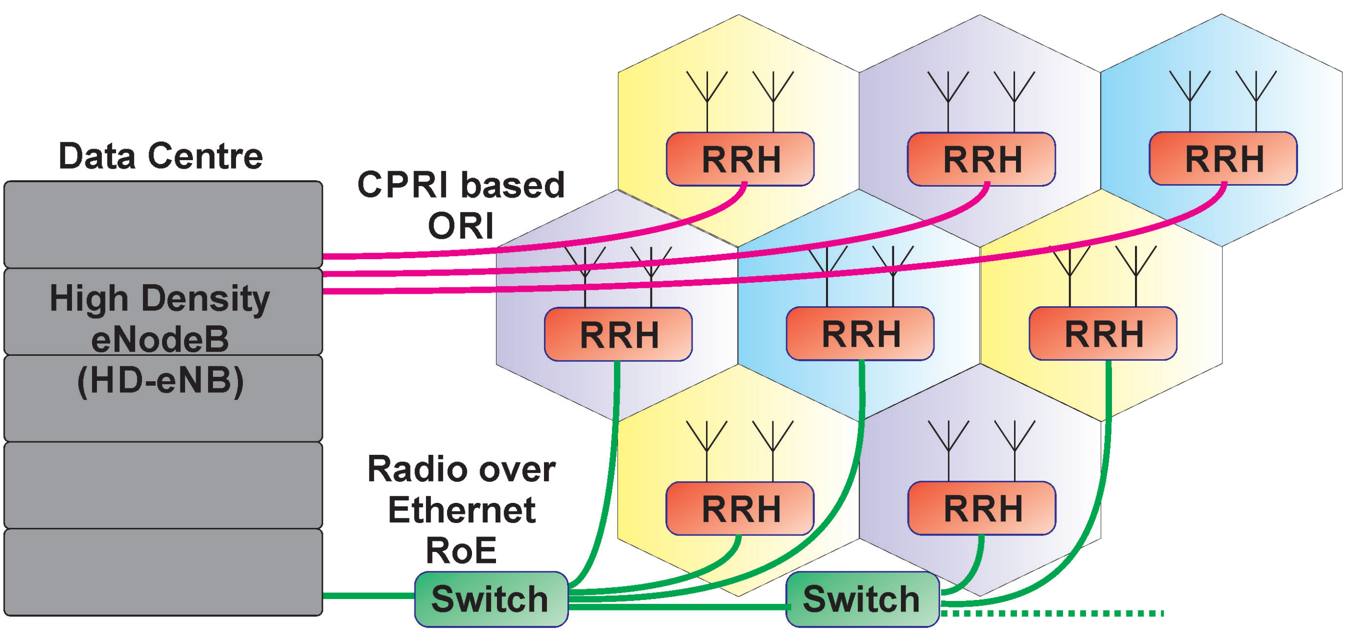
On arrival at the data center, the point-to-point CPRI technology needs to be adapted to a switchable architecture in order to terminate the traffic at available resources. This is easier to envisage with Ethernet-based technologies, or technologies built on switched fabrics such as RapioIO, but point-to-point fabrics will need some level of custom switching based solution.

For example, FPGAs could be used to discretely switch point-to-point channels under a proprietary control protocol.

Once traffic arrives at the eNodeB pool, there is much greater flexibility than at the mast-located eNodeB. Protocol stacks with visibility of multiple RRHs can aggregate network statistics from Operators, Administration and Management (OAM) data which can be used to optimize the performance of the network as a whole. For example, gathering intelligence of CQI and Sounding Reference Signal (SRS) measurements, user bandwidth demand, and Quality of Service (QoS) parameters from the EPC.

Intelligent schedulers at the eNodeB support the use of a central resource with greater processing bandwidth to improve the overall network performance, for example focusing capacity on-demand hot spots. There is the ability to switch the operational protocols of the RRH operating in specific areas, for example increasing the RRH operational bandwidth or moving to narrow-band LTE protocols where there is a concentration of IoT devices.

Organizations such as the Small Cell Forum are working to standardize how SONs deal with HetNets work with intelligent schedulers. Issues such as handover and security gateway issues in a multi-vendor SON need to be addressed. Development of a common API will go a long way to supporting this.



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Solution

Artesyn Embedded Technologies and CommAgility are well placed to address the data center-based eNodeB pool challenge.

For example, a PCI Express (PCIe) version of CommAgility's AMC-K2L-RF2 card could provide a low-cost, high-performance wideband RF transceiver and baseband processing card combined. When configured as a RRH it would support a 2x2 MIMO air interface covering frequency bands from 700MHz to 4GHz with software defined sub-bands and configurable FDD or TDD operation, and bandwidths from 1.4MHz to 20MHz. With a native power output of up to 27dBm, higher output power could be achieved using external power amplifiers; the card can provide an external control and digital pre-distortion feedback path to support this.

Such a PCIe card could perform the key analog front end functionality of the RRH:

- Digital up and down conversion (DUC and DDC)
- Crest Factor Reduction (CFR)
- Digital Pre-Distortion (DPD)
- IQ imbalance correction and nulling

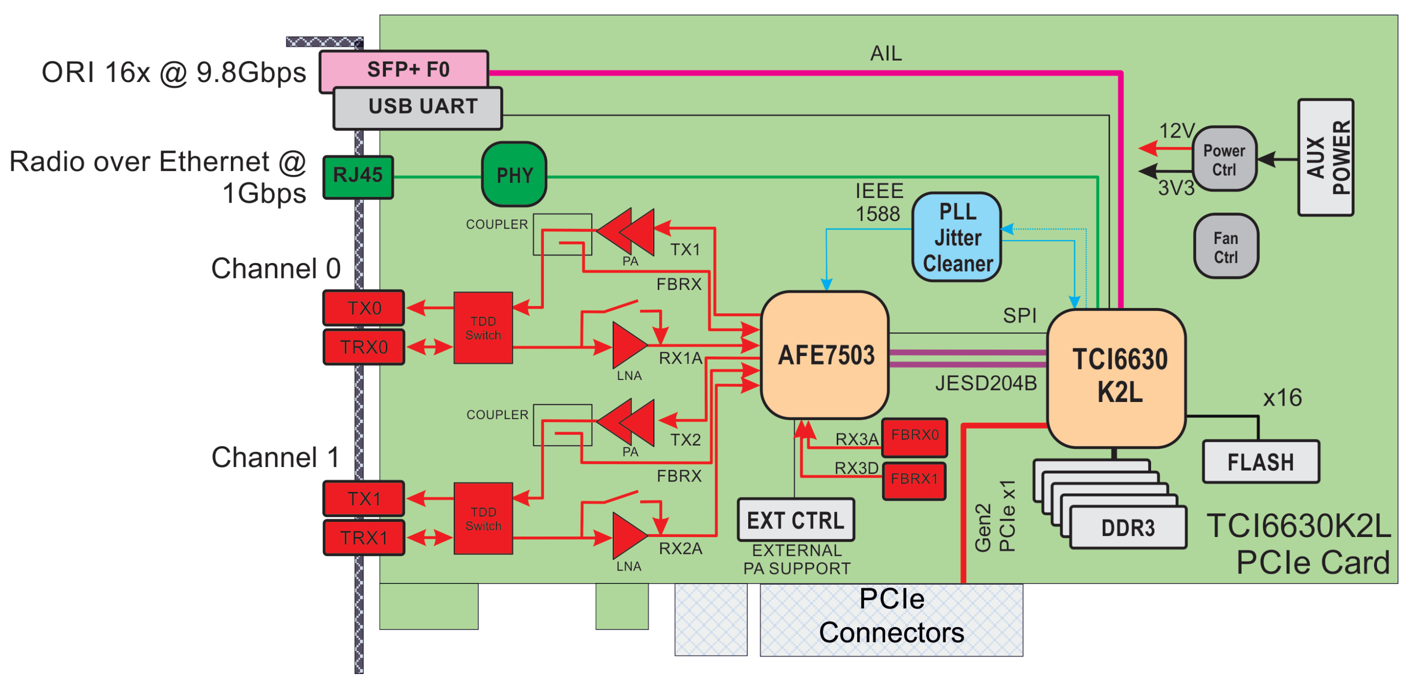
Front-haul connectivity can be supported over optical fiber using a front panel SFP+ port. The Texas Instruments TCI6630K2L SoC natively supports CPRI, but the processing provided by its four C66x DSP cores make it well positioned to develop ORI compression or RoE based solutions to reduce the front-haul bandwidth. The front haul also includes the control and management (C&M) channel to support the SDN configuration changes and the collection of CQI metrics.

Artesyn's MaxCore™ Platform family of products is ideally suited as a host system for these cards. Built around a unique PCI Express Switch, and designed for NEBS, these systems combine high flexibility in configuration with the lowest latency between different cards that form the respective system. This makes the platform a perfect solution for scalable designs from small configurations up to integration into large data centers.

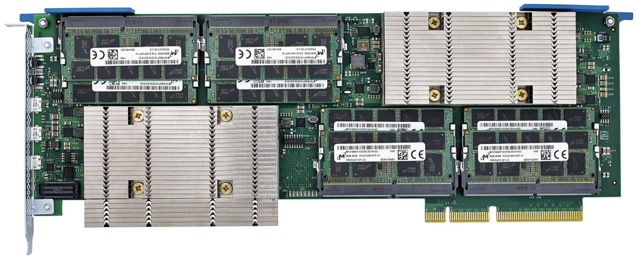
The MaxCore™ Platform from Artesyn

The fabric in the MaxCore Platform is built using the Avago ExpressFabric PCI Express switching silicon. This silicon will operate in a simple PCI Express based single root environment like any other PC, but also allows operation in a virtualized mode. By doing this, it enables operation with multiple root complexes across the same backplane as well as connecting an I/O card's virtual functions to multiple root complexes, enabling a new level of sharing of resources.

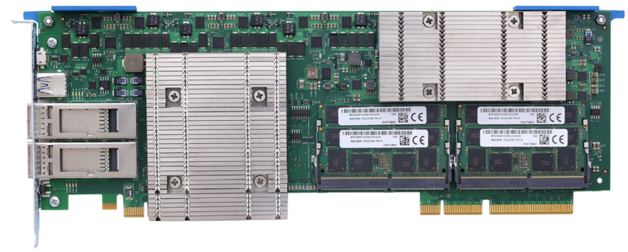
A microserver card using two Intel® Xeon® D 16-core CPU complexes and an intelligent network adaptor based on the Intel® FM10840 ("Red Rock Canyon") switch and network interface enable applications that combine connectivity to front and backhaul and, together with the CommAgility card, directly connect to RRHs in a very small form factor.



Block diagram of a PCIe version of CommAgility's AMC-K2L-RF2 card



Artesyn's SharpServer™ Microserver Card



Artesyn's SharpSwitch™ Network Adapter Card

When applied to this application, multiple Artesyn SharpServer™ microserver cards and multiple Artesyn SharpSwitch™ network adaptor cards can be combined with the CommAgility PCI Express card according to the performance requirements of the actual deployment to create complete single or multiple eNodeBs in a single enclosure. In this context, the solution is scalable from a small system suitable for a sporting venue server room location or a full central office.

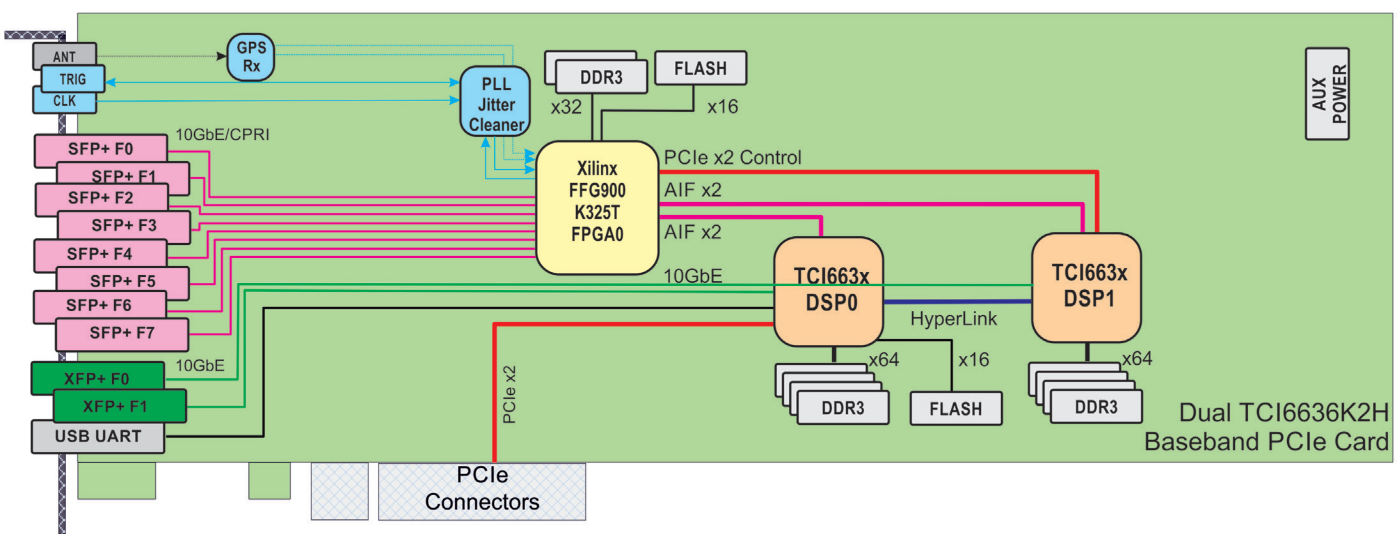
The SharpServer cards act as a scalable pooled resource running the CommAgilty SmallCellSTACK software across multiple cards in the solution. By building an intelligent scheduler within the stack, access can be provided to network statistics from all of the supported PHYs and the developer can allow control of the RRH configuration over the front-haul control and maintenance channels. It is also a suitable location to host the EPC in small local networks, providing a self-contained server-hosted network.

The glue between the protocol stack and the DAS is the PHY. The PHY and its partitioning is probably the greatest area of discussion within the C-RAN architecture. CommAgility's AMC-D24A4 is a high-performance highly-configurable processing card which has the flexibility to support multiple variations of Cloud RAN architectures. Designed for rack-mounted chassis based systems it can be readily adapted for the data center server. For example, refer to the board diagram below.

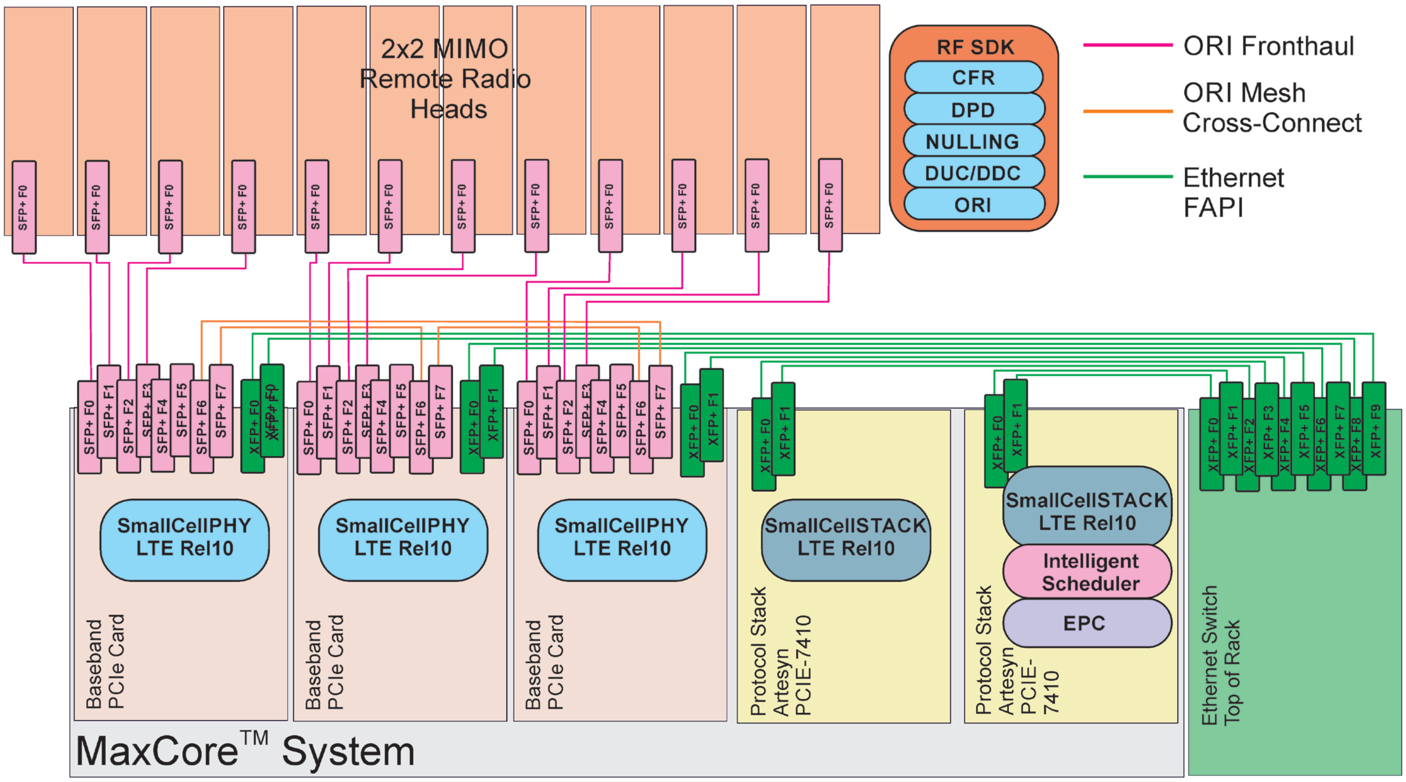
Such a card can support up to eight ORI connections to optical front SFP+ ports. The FPGA can be configured to perform the ORI decompression and send channels back to the DSP for baseband processing. Alternatively, ORI switching support can be added to the FPGA to re-balance the baseband load across multiple baseband cards in the system as shown in the system diagram below.

An alternative solution using RoE can be readily achieved using a similar architecture. In this case, the RRH implements a RoE protocol on the DSP and the Gigabit Ethernet (GbE) links from the RRH are terminated at the server, either directly to the FPGA SFP+ connectors or via the top-of-rack switch. The baseband card FPGA can then implement RoE routing and termination to balance the processing load.

Connection between the PHY and stack is supported by the Small Cell Forum Femto Application Programming Interface (FAPI) to provide an open standard MAC-PHY API.



Block diagram of a PCIe version of CommAgility's AMC-D24A4 baseband processing card



Multiple Artesyn SharpServer microserver cards and multiple Artesyn SharpSwitch network adaptor cards can be combined with the CommAgility PCI Express card in an Artesyn MaxCore platform according to the performance equirements of the actual deployment to create complete single or multiple eNodeBs in a single enclosure.

Conclusion

Although 5G brings challenges to the conventional network architecture, the re-imagining of that architecture for 5G also bring opportunities to support functionality not previously achievable. In this paper we have discussed some of the emerging technologies and routes which can be taken to exploit these new technologies.

We find that that the majority of the building blocks already exist. But to fully realize the potential of a server-room based solution, the blocks need to be integrated so that flexible hardware configuration and low-level access to protocol stacks work in tandem.

By combining the Artesyn and CommAgility product lines, an integrated solution can be built from these components that perfectly scales from very small to very large deployments, using the same basic infrastructure as well as the same software.

About CommAgility

CommAgility is an award-winning, world-leading developer of embedded signal processing and radio modules for 4G and 5G mobile network and related applications. We design the latest DSP, FPGA and RF technologies into compact, powerful, and reliable products based on industry standard architectures. Our customers around the world integrate CommAgility products into high performance test equipment, specialised radio and intelligence systems, R&D demonstrators and trial systems. We are highly flexible and work closely with our key customers to meet their technical needs and to support them through development into volume production.

CommAgility was honoured with a Queen's Award for Enterprise in International Trade in 2013, appeared in the Sunday Times Hiscox Tech Track 100 list of fastest growing technology companies in 2015, and featured in the Deloitte UK Fast 50 in 2013 and 2012.

In March 2015, CommAgility acquired MIMOon GmbH, headquartered in Duisburg, Germany, a leading licensor of LTE Software IP for mobile devices & wireless infrastructure. MIMOon's portfolio of products includes Physical Layer and Protocol Stack (SmallCellPHY and SmallCellSTACK) for Small Cells, Physical Layer and Protocol Stack for terminals (MobilePHY and MobileSTACK), advanced scheduler for small cells (SmallCellSPECTRUM) and IP development in the areas of advanced PHY algorithms on multi-core SDR platforms.

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About Artesyn Embedded Technologies

Artesyn Embedded Technologies is a global leader in the design and manufacture of highly reliable embedded computing solutions for a wide range of industries including communications, military, aerospace and industrial automation.

Building on the acquired heritage of industry leaders such as Motorola Computer Group and Force Computers, Artesyn is a recognized leading provider of advanced network computing solutions ranging from application-ready NFV platforms, server acceleration platforms, and add-in acceleration cards to enabling software and professional services.

For more than 40 years, customers have trusted Artesyn to help them accelerate time-to-market, reduce risk and shift development efforts to the deployment of new, value-add features and services that build market share.

Artesyn has over 20,000 employees worldwide across ten engineering centers of excellence, four world-class manufacturing facilities, and global sales and support offices.

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