RAN Virtualization Goes Beyond C-RAN with RF Routing

February 2015

INTRODUCTION

Modern mobile communications networks are in the midst of profound architectural changes as they adapt to exploding volumes of fdpamobile traffic as mobile network operators (MNOs) fight to maintain or minimize capital expenditure (CAPEX) and operational expenditure (OPEX) while maximizing coverage and capacity on their increasingly congested networks.dpa

The situation is no less serious for in-building or in-venue wireless systems and perhaps even more demanding for the MNO, owner, or operator since, by many accounts, about 80% to 95% (depending on the venue and the market) of mobile traffic is consumed and / or generated indoors. Conventional in-building wireless systems use distributed antenna systems (DAS) but other technologies such as Wi-Fi and small cells are also good choices in some situations.

ABI Research believes that radio access network (RAN) virtualization is one of the top-five technology disruptors[1] and a technique that is rapidly being brought to bear on solving these challenges. One of the first applications to feature RAN virtualization will be in-building and in-venue wireless systems, wherein a virtualized system distinguishes itself from conventional DAS, centralized or cloud RAN (C-RAN) and small cell systems by offering low total cost of ownership (TCO) and technology-agnostic RF distribution with autonomous capacity steering for higher system utilization. In fact, one of the important key performance indicators (KPIs) is the number of gigabytes transported per TCO dollar spent, and ABI Research expects

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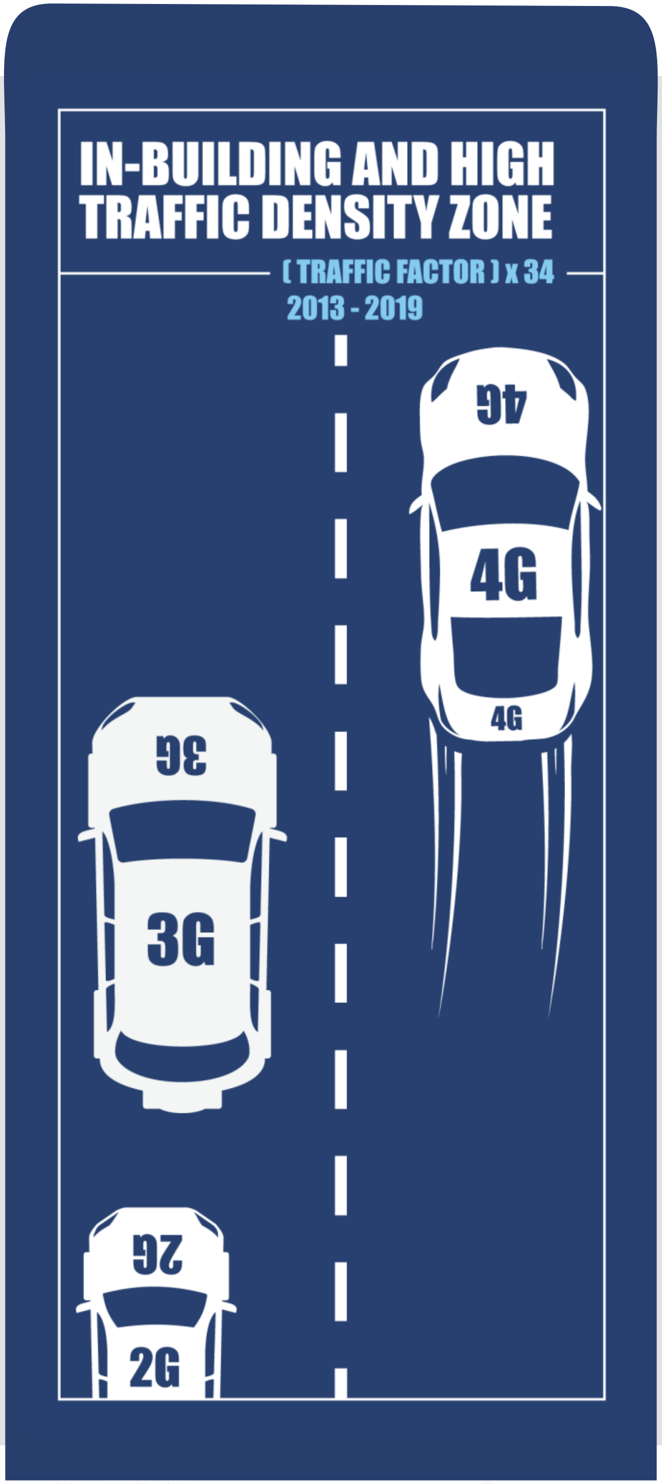
that virtualized RAN systems will see an increase in this KPI when compared to conventional DAS systems.

This whitepaper discusses the adoption of RAN virtualization in indoor and venue systems and outlines the solution from Dali Wireless, an early innovator and leading vendor of virtualized, digital RF routing or distribution solutions for in-building wireless systems.

MAJOR TRENDS DRIVING IN-BUILDING AND HIGH TRAFFIC DENSITY ZONE WIRELESS

Based on estimates of mobile network traffic by access technology, ABI Research forecasts that worldwide growth in 4G mobile traffic will outpace that of 3G and 2G. 4G traffic will grow by a factor of 34X between 2013 and 2019, and for the first time 4G traffic will exceed all other traffic sometime during 2015, while 3G technologies will continue to grow and 2G technologies will slowly decline. It is against this backdrop that MNOs must act to support these technologies for the foreseeable future.

This is not the only characteristic of mobile network traffic that is changing, however. MNOs must also adapt to the changes in subscriber usage patterns, which are driving network densification. One of the reasons 4G traffic grows so rapidly is due to the "4G Multiplier Effect." The inherently high data rates available in 4G mobile networks encourage subscribers to consume more data and this multiplies or compounds the growth in traffic as they are motivated to take advantage of the high throughput to access even more applications. Modern smartphones and tablets have evolved to become powerful handheld computers and the trend is for subscribers to use an increasingly data-rich variety of applications.



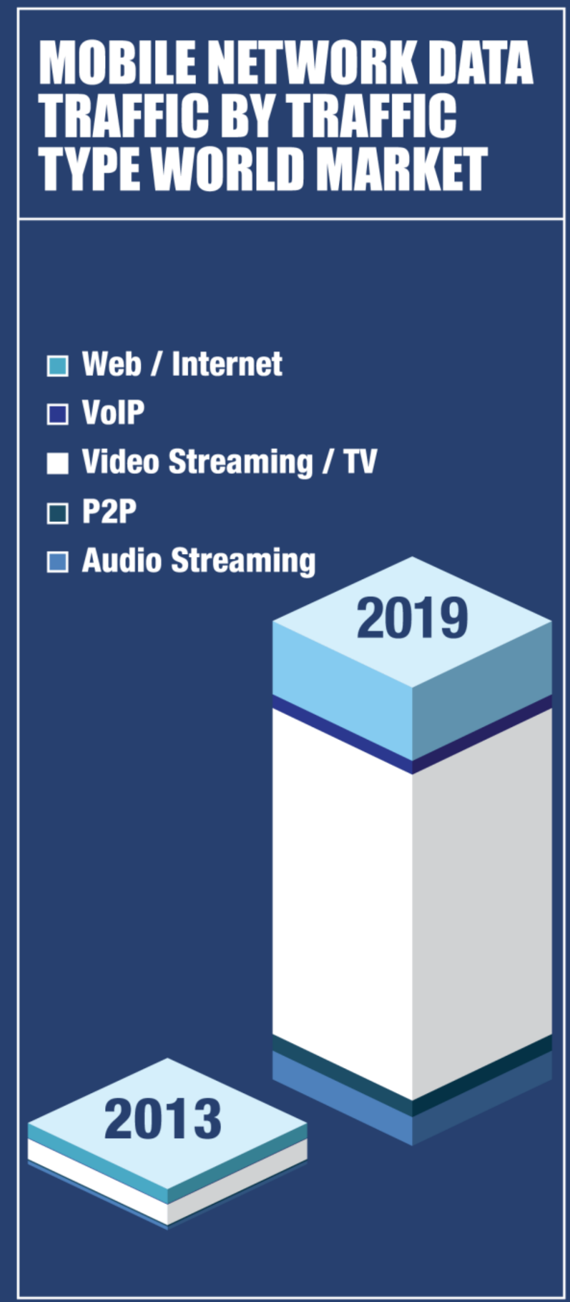
A third characteristic of mobile traffic is that the fastest-growing and dominant traffic type is video traffic, and ABI Research estimates that video traffic will grow by 17X between 2013 and 2019. As a result, mobile networks must handle video traffic efficiently by offering low jitter with high-bandwidth access in comparison to other traffic types.

When considering indoor or venue deployments, wherein 80 to 95% of all mobile traffic is generated or consumed, it is data and video traffic that dominate, with voice, audio streaming, and VoIP traffic consuming less than 10% of traffic and an acceptable data session requiring at least 100X of the bandwidth of a good voice call.

A further consideration is that traffic patterns are not constant. Bandwidth demand shifts according to the time of day and location, with more traffic generated during working hours in enterprises, transportation hubs, and shopping malls when compared to evenings, for example. An indoor or venue wireless system must be flexible enough to cater for this “tidal ebb and flow” of traffic.

When offering mobile service indoors, MNOs and building owners must take into account all of these factors to offer always-on, high-bandwidth, low-latency, and low-jitter connectivity deep inside buildings and venues of various types. This is in addition to tackling the traditional radio signal propagation issues due to building materials such as concrete, steel, metal film window tint, and low-E glass, all of which attenuate the RF signals, particularly at the higher GHz-range frequencies in use today.

The deployment scenarios that operators face are challenging with varying degrees of complexity. These include small-to-medium and large enterprises, transportation hubs such as airports, metros, or subway systems, sports venues and stadiums, public areas, and convention centers to name a few. Many systems of varying types



are on offer today from macrocell vendors, small cell vendors, and DAS vendors, all vying to provide coverage and capacity in buildings and venues.

Conventional DAS (both active and passive) and now small cells and Wi-Fi can all be leveraged to assist the MNO in providing coverage and capacity indoors. However, given the challenges outlined above, it has become increasingly apparent that conventional DAS and small cells do not scale well and can actually add operational complexity and cost to an in-building system. Conventional DAS does not economically scale down to small- to medium-size deployments, while small cells do not easily scale up to very large installations.

It is against this backdrop that RAN virtualization comes to the rescue. The ability of the technology, when built on RF routing, to offer low TCO, technology-agnostic RF distribution with autonomous capacity steering, and system optimization is a key success factor for in-building wireless systems. It is this that allows the MNO or system owner to manage TCO while delivering on user experience and growing revenue.

MARKET POTENTIAL

The total market potential for equipment employing RAN virtualization is a combination of the market for in-building wireless systems, which includes active and passive DAS and repeaters, enterprise femtocells or small cells, metrocells, and enterprise Wi-Fi.

Based on a compilation of ABI Research forecasts for each of these types of equipment, we can see in the chart that between 2014 and 2019, the equipment market grows by 3X to reach a value of more than US$25 billion.

The regional differences can be seen in the chart shown opposite, which plots the same data and illustrates that, although North America was the largest market in 2014, it is the Asia-Pacific region, growing by 4X, which becomes the largest market in 2019. Other regions grow by between 2X and 3X in the same time frame. In 2019, the market in the Asia-Pacific region will exceed that of North America by 35% according to ABI Research's estimates.

These figures include equipment but exclude the one-time installation and system integration revenues that would attract system installers and system builders.

RAN VIRTUALIZATION DEFINED

In a conventional 2G, 3G, or 4G RAN, a radio base station contains a baseband for digital processing of the radio protocol and a radio unit for transmission and reception of the radio signals. The situation wherein the baseband and radio unit are collocated is the standard base station configuration.

In many situations today, the base station can be partitioned into the baseband (which is shared among multiple cells) and remote radio heads in such a way that a single base station is connected to and operates multiple remote radio heads: one per cell. This setup is common wherein a base station operates several sectors of the RAN, for instance. The connection between the baseband and the remote radio head, or fronthaul, must be high-speed, low-latency transport such as fiber, wherein typical data rates can reach 10 Gbps in the cases wherein multiple in multiple out (MIMO) is used and that require low delay and high-precision synchronization.

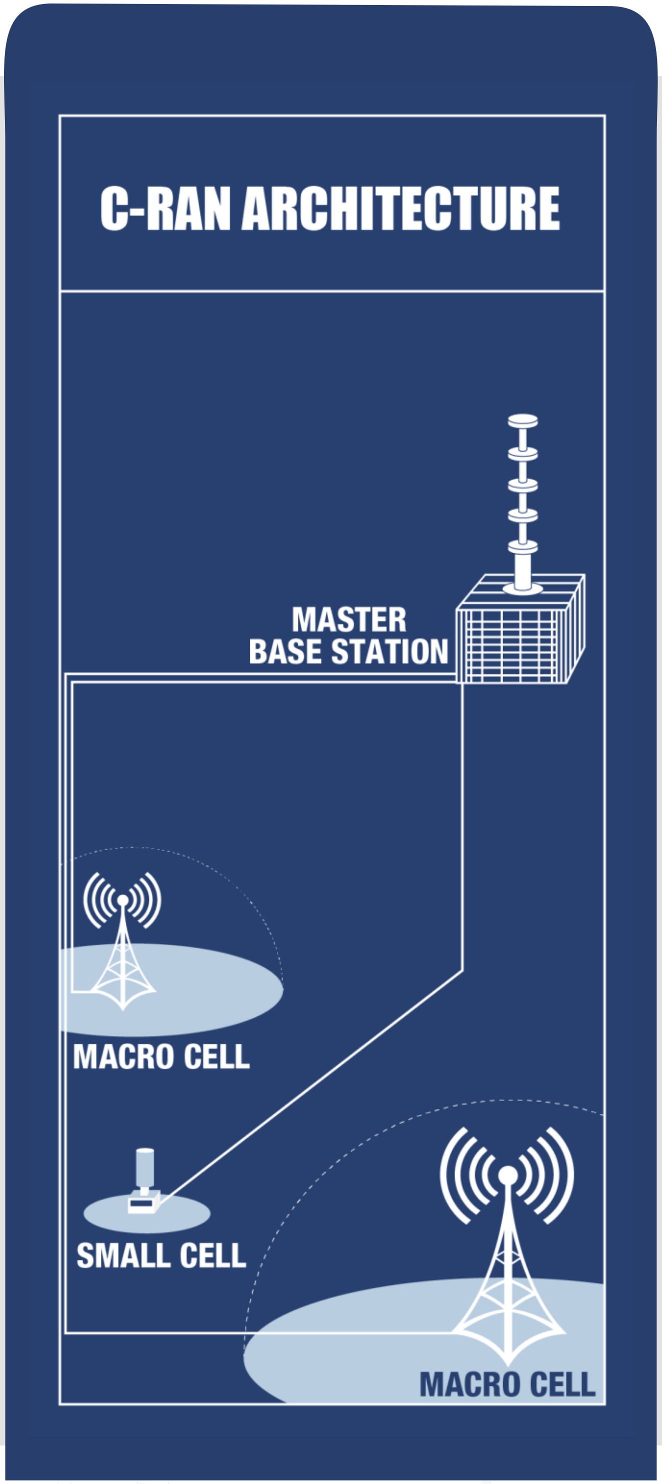
The advantages of this architecture are that lower RF losses are incurred between the radio and the antenna, since shorter lengths of coaxial cable can be used. Also, antennas can easily be physically separated for diversity or MIMO systems.

To enable this architecture, an industry common interface standard was needed between the remote radio head and the baseband portion of the base station. The Common Public Radio Interface (CPRI) specification was defined by a consortium of major companies engaged in mobile wireless infrastructure and was originally released in 2003. The CPRI specification defined the internal interface between these two major sections of the base station.

Most commercially available remote radio heads available today use the CPRI interface, although an alternative standard, the Open Base Station Architecture Initiative (OBSAI), is also used in some cases. CPRI fronthaul offers minimal latency and near-zero jitter and bit error rate, and can be transported using dark fiber, optical transport network (OTN), passive optical network (PON), dense wavelength division multiplexing (DWDM), coarse wavelength division multiplexing (CWDM), and microwave / millimeter wave.

Neither the CPRI nor OBSAI standards ensure interoperability between different vendors; however, as we shall see, the use of an RF Router in the virtual RAN guarantees that the system becomes vendor agnostic.

When this type of distributed architecture is used for indoor and venue RF distribution, the centralized baseband concept can be defined to support many remote radio heads. Taking advantage of the power of digital processing in the baseband, the radio interface of each cell is controlled by a scheduler that allocates radio resources to the various bearers and, consequently, to sessions required by the user terminal and cell. The single baseband is located in a telecom closet in the building, which is in a central location, and for every MNO, an additional baseband is collocated. This architecture is defined as a centralized RAN (C-RAN) and is the first step toward virtualization of the RAN.

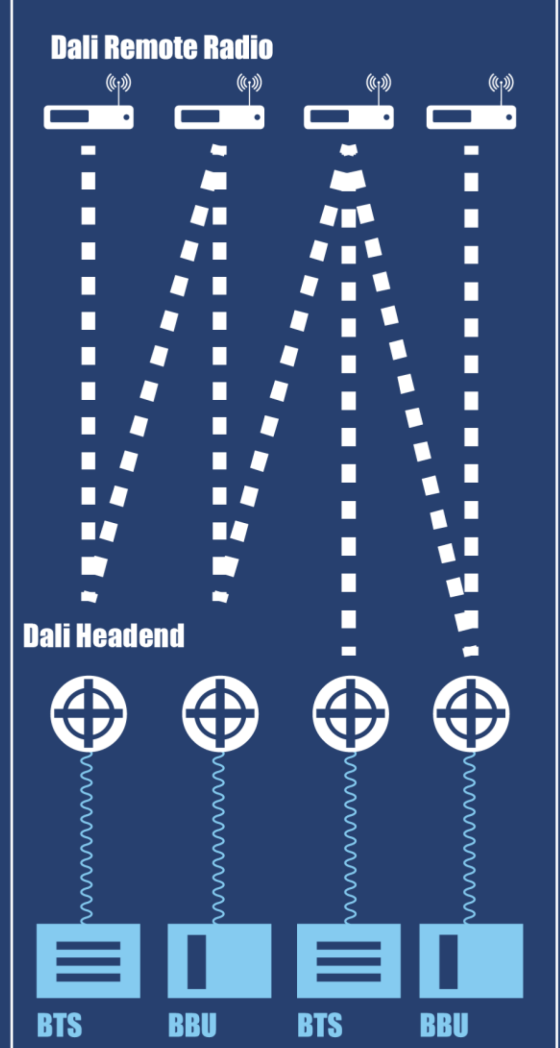


The drawback of C-RAN used for in-building wireless distribution is that the potential cost reductions remain elusive since the baseband typically only accounts for about one third of base station CAPEX. The C-RAN also has a limited ability to adapt to changing RF distribution requirements such as the tidal ebb and flow of traffic patterns or the ability to scale up without system reconfiguration or hardware add-ons. This means that to avoid situations in zones where data sessions are blocked due to traffic congestion, the system must be provisioned by optimizing both baseband and air-interface capacity for higher utilization, thereby eliminating the tendency to overprovision and also helping to lower costs.

In a virtual RAN, the base stations are virtualized or abstracted in such a way that all the smartphones and handsets within range or camping in the coverage area of the remote radios have full access to the combined baseband and radio resources of all of the virtualized base stations. This architecture is reminiscent of virtual computing, in which processes running in a virtual machine have access to all the physical central processing unit (CPU) resources of the hardware host, and for each individual process, access to those resources is assigned by a hypervisor. In a virtual RAN, access to the baseband and radio resources is managed by a RF router, the equivalent of a hypervisor. It is the RF router that assigns these resources to the user terminals camping in the coverage areas.

The ability to offer RF routing is responsible for a TCO reduction in that in-building wireless systems no longer need to be designed for peak capacity any time and anywhere within the building. Peak demands are handled by altering the configuration of the system remotely or autonomously, thus saving on hardware costs. It is the removal of the need to overprovision hardware to accommodate the highest peak loads any time and anywhere that is responsible for the TCO savings.

RAN VIRTUALIZATION COMES TO THE RESCUE



The advantage of the RF router as a virtualization vehicle also lies in its ability to virtualize scarce spectrum resources. Whereas baseband resources can, in theory, be increased almost without limit (ignoring cost, of course), spectrum is inherently limited and its virtualization is, by far, more effective and desirable.

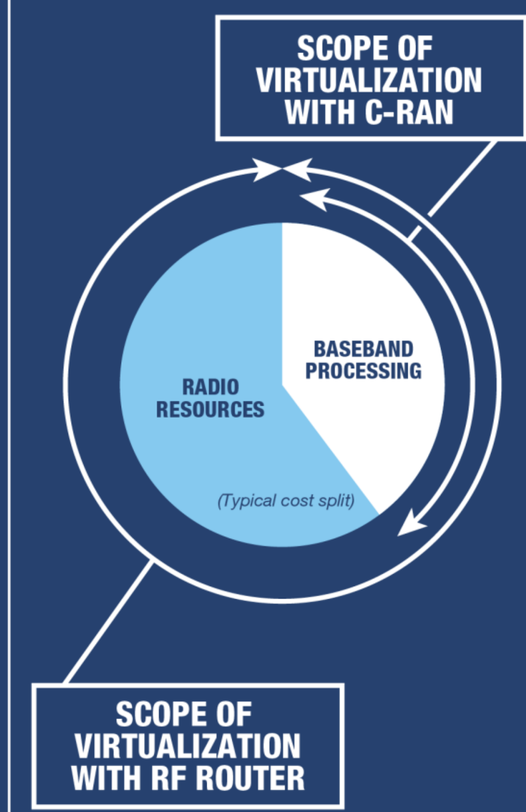
RAN virtualization, enabled by the RF router platform, goes beyond conventional C-RAN to help the system owner or operator improve the operational efficiency of the system. RAN virtualization permits remote configuration and redistribution of radio coverage and capacity to each antenna in the system.

BENEFITS AND USES OF RAN VIRTUALIZATION

ABI Research has discussed how RAN virtualization built on a C-RAN foundation can save costs by avoiding overprovisioning, which is one of the main drivers of TCO reduction. Virtualized RAN architectures are inherently more flexible than traditional base stations or small cells. Virtualized RAN systems can also be scaled up without the overprovisioning of radio resources or remote radios. Finally, virtualized RAN offers benefits from pooling, sometimes called “trunking gain,” which means that capacity is exactly matched to demand, thus removing the need to provision every point in the network for peak performance. Peak demands are handled by altering the configuration of the system remotely or autonomously, thus saving on hardware costs.

There are many other benefits that can be obtained from a virtualized RAN. These include savings in energy and improved user quality of experience (QoE) since the basebands are centralized or pooled and the air-interface resources are scheduled to only those tasks required. Improved QoE is equal in importance to or even more important than reductions in TCO, and assists the MNO in retaining or increasing subscribers.

TYPICAL COST SPLIT OF BASE STATION MODULES AND SCOPE OF VIRTUALIZING FOR C-RAN AND RF ROUTER



Another desirable feature of a virtual RAN and also a C-RAN, both of which may use fiber for RF distribution, are their “green” credentials for a reduced carbon footprint. In these architectures, the main driver in reducing energy consumption is the avoidance of feeder cable losses that, in many cases, can consume up to 50% of the power output of the centralized base stations.

Also, since the distance from the user terminal to the remote radios is short in in-building situations, the RF transmit power can be reduced without any effect on QoE, resulting in further energy savings for the system and also longer battery life for the user’s terminal. Finally, since the baseband pool is a shared resource, it means a much more efficient use of processing resources, and hence power, can be achieved. For example, when a base station is idle at night, most of its processing power is not needed and it can be selectively taken to a low-power or standby state without affecting the 24 / 7 service availability commitment.

The RF router is, in fact, very effective in high-density situations such as venues and enterprises where traffic congestion can easily exhaust network resources. Compared to other types of architectures such as small cells, the virtualized RAN can easily make use of the Third Generation Partnership Project (3GPP) Rel10 and Rel11 Coordinated Multi-Point (CoMP) and / or enhanced Inter-Cell Interference Coordination (eICIC) to mitigate interference between cells. Instead the use of simulcast (highly synchronized signals across cells) made possible by the RF router avoids interference at all. These CoMP and eICIC techniques are normally only required by small cells, which can coexist with the virtual RAN, but which create significantly increased complexity in signaling as well as in planning and operation when compared to the virtual RAN.

The virtualized RAN’s ability to offer dynamic capacity steering is another considerable benefit. As we shall see in the case of Dali Wireless, the feature works

BENEFITS OF RAN VIRTUALIZATION

- RAN Virtualization built on a C-RAN Foundation
- Save Costs
- Savings in energy
- Total Cost of Ownership
- More Flexible than traditional basestations or small cells
- System Performance & Capacity
- System Performance & Capacity can be Improved especially at the edges of cells
- Capacity is Exact Match to Demand
- Reduced Carbon Footprint
- More Efficient utilization rate

in much the same way that packet switching works for mobile networks or Internet traffic. The RF signals are digitized and packetized by the RF router so they can be directed to any antenna or coverage area, effectively establishing a multipoint-to-multipoint architecture. The DAS network management system (NMS) can then be programmed to direct traffic automatically according to demand.

RF routing used in a virtualized RAN easily supports MIMO, which offers increases in data throughput and range without increasing link bandwidth or transmit power. MIMO works best in a multipath environment, with uncorrelated multiple paths on the same frequency connecting the transmitters and receivers and MIMO compensating for a potentially high signal-to-interference-plus-noise ratio (SINR) in the channel. Thanks to multipath, indoor and venue deployments with walls and furniture promise excellent performance potential for MIMO and DAS.

When comparing the various approaches for in-building coverage, ABI Research can contrast the more traditional alternatives with virtualized RAN. The virtualized RAN architecture has the ability to offer best-in-class performance for number of concurrent users, range and efficiency, and it is best suited for complex venues with variable capacity demand. This is not to say that virtualized RAN is the only solution. In fact, the “toolbox” of solutions for in-building wireless includes Wi-Fi, femtocells, small cells, and conventional DAS for every deployment scenario ranging from residential and isolated deployments to enterprises and indoor / outdoor venue deployments.

DALI’S RAN VIRTUALIZATION

The foundation upon which Dali’s virtual RAN solution is built is the RF Router® described in its June 2014 whitepaper[2].

BENEFITS OF RAN VIRTUALIZATION

CONTINUES...

Makes use of the 3GPP Rel10 and Rel11 CoMP and or eICIC to mitigate interference between sectors and nodes

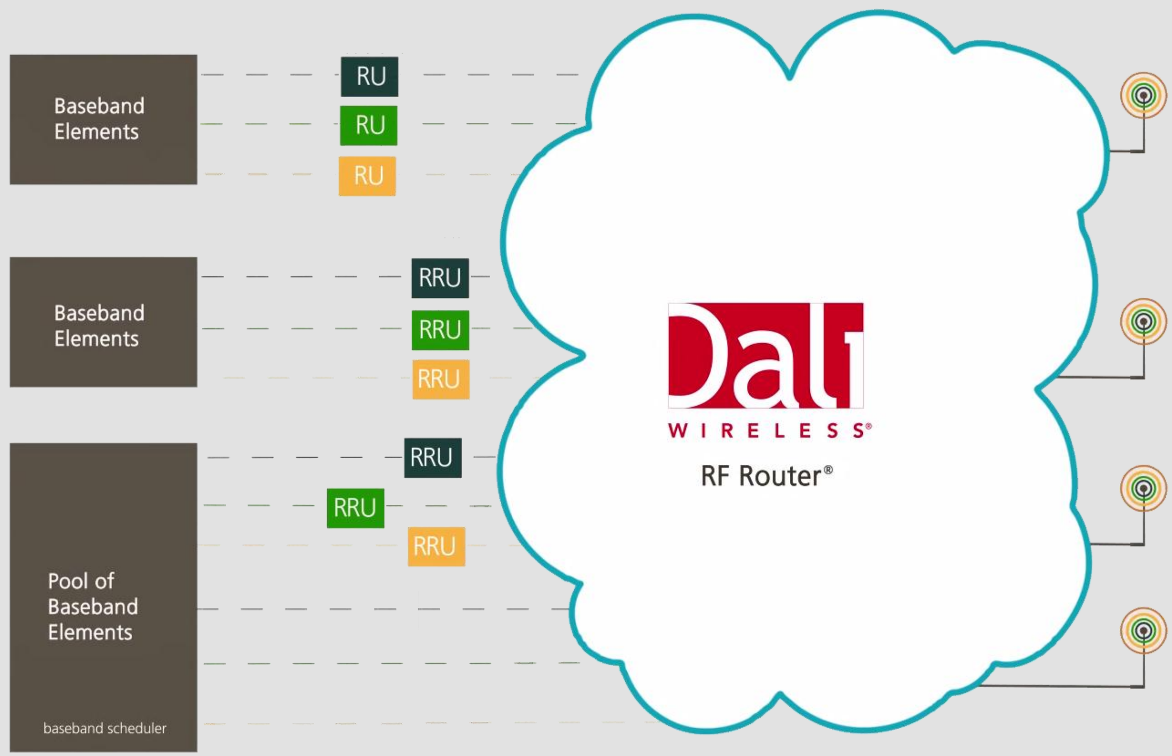
Dynamic Traffic Steering

Easily Supports MIMO which Offers Increases in Data Throughput & Range without increasing link bandwidth or transmit power

The RF Router operates by providing end-to-end digital signal processing, and can, therefore, be flexible in distributing RF signals from multiple base stations to be regenerated at any of a number of remote radio modules, as shown in the figure below.

Figure 1: Dali Wireless Virtual RAN Architecture

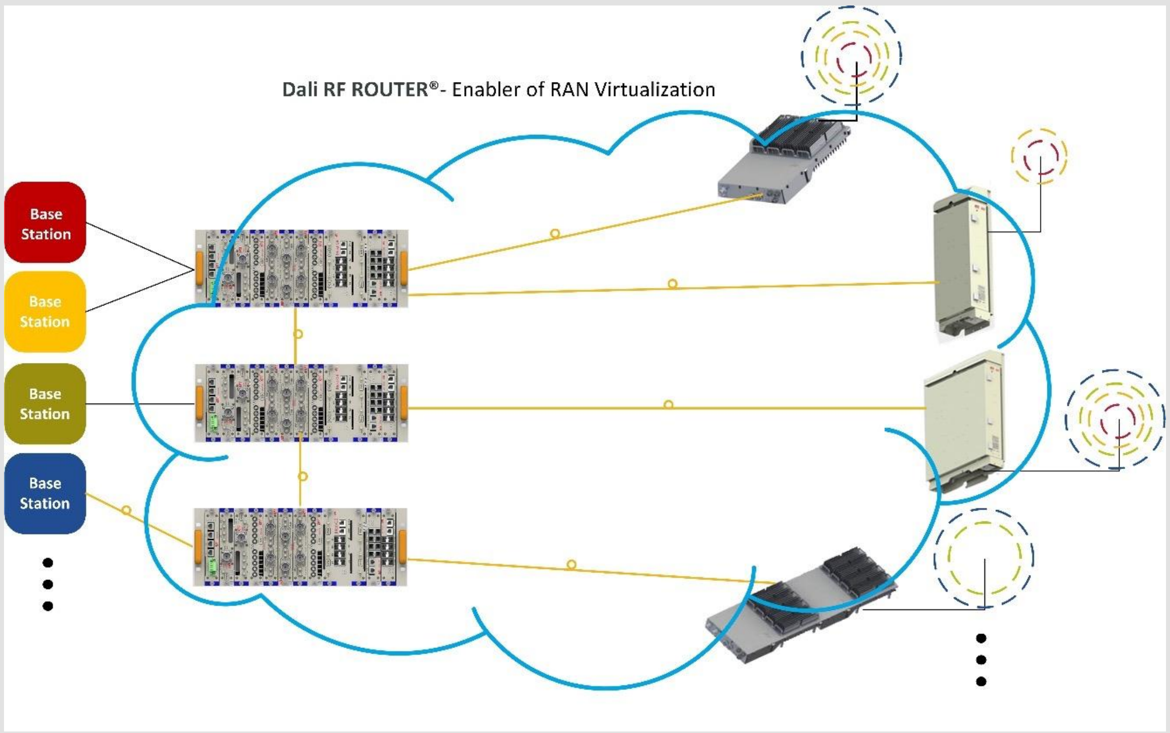
(Source: Dali Wireless)



Dali's RF Router platform consists of two main components: the host unit (headend) and the radio remotes. As shown in the figure above, the host unit interfaces with the feeder base stations using an RF interface such as the radio unit (RU), a remote radio unit (RRU), or a digital baseband interface (BBI), and it uses the industry-standard CPRI protocol.

Figure 2: Dali Wireless RF Router

(Source: Dali Wireless)



The host unit converts the signals (delivered from RU and RRU) to CPRI frames and converts all the data streams from all sources into addressable packets so they can be delivered individually to one or more remote radios. In this way, radio capacity can be directed from any source to any destination point within the network, irrespective of the underlying physical distribution network, as shown in Figure 2 above.

The host aggregates these packetized digital RF signals and converts them to an optical signal for transport over fiber at a rate of up to 10 Gbps to one or more radio remotes. Dali uses a single optical transceiver for both uplink and downlink signals, which means that a single fiber is used for both transmit and receive signals. In this way, the number of fibers required for any given deployment is reduced and this, in turn, reduces the cost of deployment and operation. Also, in the Dali network, an IP-pass-through mode is available. A transparent 1-Gbps Ethernet channel on each fiber connection can be used to carry IP traffic from Wi-Fi access points or other IP devices such as webcams, electronic messaging boards, digital announcement systems, surveillance cameras, or other IP-based equipment. If needed, the Ethernet channel data rate can be remotely provisioned to support a higher data rate.

Dali has created a multipoint-to-multipoint logical network that permits RF signals to travel from any source to any destination regardless of the underlying physical network. This, in other words, is the enabler of the virtual RAN.

Radio remotes support four or eight bands with full-band, instantaneous bandwidth per band. Multiple versions of the radio remotes are available to provide different combinations of frequencies and output RF power. The radio remotes come in low-, medium-, and high-power versions (1W, 5W, and 20W ERP per band). The radio remotes are available in indoor and outdoor versions and can be mixed and matched as needed. Digital predistortion and crest-factor reduction techniques are implemented in the remote radios to maximize efficiency and improve amplifier linearity to within the specifications of the access technology, and also to reduce power consumption.

The modular design of Dali's radio remote portfolio means that it can support any combination of four to eight RF bands in a single radio remote, including multiple RF modules operating on the same band, *e.g.*, for MIMO deployments. All U.S.

bands and the European / Asian bands for GSM, UMTS, and LTE, as defined by 3GPP, are supported.

The technology Dali uses also includes digital compensation to ensure that the signals to and from each radio remote are synchronized with low jitter to less than 35ns. This level of precision exceeds 3GPP LTE requirements for MIMO by a factor of two. Since MIMO performance is sensitive to phase synchronization or jitter and balanced power between the radio remotes, this capability is effective in implementing high-performance MIMO. Tight synchronization is also a prerequisite for simulcast operation, and precise simulcast is key to enabling efficient MIMO and avoiding interference between adjacent radios.

The RF Router solution is base station-vendor agnostic, and operates on any frequency band specified by the 3GPP and with any technology and radio modulation scheme used in GSM, UMTS, HSPA, and LTE RANs. The RF Router also respects the differing requirements of multiple MNOs by separating the signals and configuration parameters of each MNO sharing the same RF Router infrastructure and allowing for independent control of the network parameters on a per-operator basis.

Finally, with Dali's Network Management System, NMS 2.0, the RF Router can dynamically and autonomously allocate the various feeds coming from multiple base stations to different antenna points in the radio network. The dynamic capacity allocation is fully controlled and performed by this software. This full multipoint-to-multipoint routing between cell feeds and antennas enables a layer of virtualization across the entire set of base stations, including their radio units.

This approach is similar to server farms, which also leverage virtualization and have become dominant in the computing world for complex or large computing tasks. In a server farm, numerous computer servers are interconnected together physically and logically, and housed within the same physical facility. The server farms have become the engines of cloud computing. Similarly, a base station farm differs from a traditional base station hotel in the same sense that a server farm differs from a collection of discrete computers collocated in the same room.

In a base station farm, mixing and matching of different base station vendors becomes possible, as does the pooling of baseband and radio resources. All the base stations in a base station farm are interconnected physically and logically *via* a network of RF Routers. This "farm" is not necessarily restricted to physically collocated base stations, however. When more wireless capacity is needed, more base station resources can be added to the farm, while leaving the rest of the physical RF distribution network intact. If more coverage is needed, more radio resources are simply added at the remote side to the desired radiating location. This flexible, modular approach, whether in the radio world or the computing world, is a direct result of virtualization technology.

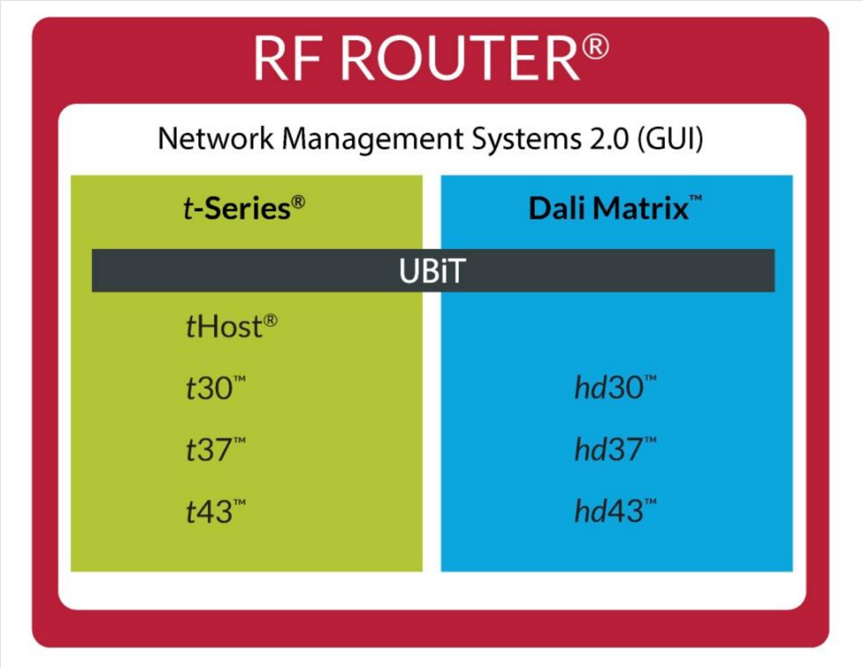
Dali Wireless's RF Router product portfolio has two offerings: (1) the *t*-Series® and (2) the Dali Matrix™. Both the *t*-Series and Matrix share the same Universal Base station Interface Tray (UBiT) chassis and related RF interface modules, which serve as active points of interface (POIs).

The *t*-Series consists of the host (*t*Host®) and a suite of low-, medium-, and high-power remote radio units (*t*30™, *t*30x™, *t*37™, *t*43™, *t*43x™) with 6-Gbps digital transport.

The state-of-the-art Matrix is designed with modularity in mind to handle easy expansions and upgrades in the rapidly evolving mobile networks. Matrix consists of UBiT, which combines the functions of the host and the active POI, and a suite of modular remote radio units that come in low, medium, and high power (*hd*30™, *hd*37™, *hd*43™). Matrix supports digital throughput of 10 Gbps over a single optical fiber. The UBiT contains host modules, RF interface modules (Active POI), and baseband interface modules that can be mix and matched for evolving needs.

Figure 3: Dali Wireless RF Router Portfolio

(Source: Dali Wireless)



CONCLUSIONS

The explosion in mobile data is driving fundamental architectural changes to the RAN as MNOs struggle to maintain or minimize CAPEX and OPEX, maximize coverage and capacity, and consequently user experience on their increasingly congested networks.

Virtualization is emerging as a major technology driver in telecommunications. By embracing the principles of software-defined networking / network functions virtualization (SDN / NFV), virtualization offers a way of reducing cost and complexity in the network and of improving its performance.

Although many network functions are being virtualized in mobile networks, one of the first areas that will see the RAN virtualized is in in-building and in-venue wireless scenarios. RF distribution systems for these wireless deployments are evolving rapidly to enable the concepts of a virtualized RAN architecture by building on top of and extending C-RAN.

As in-building wireless systems evolve from 3G and 4G toward 5G and beyond, they will require fiber backhaul / fronthaul transport, neutral hosting, and autonomous and dynamic capacity allocation, and will be access technology and MNO agnostic. In this way, the virtual RAN based on advanced digital DAS architecture will offer significant advantages over conventional DAS and small cell deployments and become economic for deployments ranging from medium-size buildings to very large installations. Deployment scenarios wherein small cells do not scale up well and conventional DAS is too expensive for the required level of performance are ideal for a virtual RAN digital DAS. Dali's RF Router offers an economical alternative that surpasses conventional DAS systems in performance, functionality, power, and TCO.

The key underlying technologies in Dali's virtual RAN give it an early time-to-market advantage in capturing a meaningful share of this growing multibillion dollar market opportunity, in which the in-building wireless market blends with the indoor / outdoor small cell market. The hallmark of Dali's virtual RAN is the many-to-many relationship between baseband, radio, and antenna. Only this approach allows for virtualization of not only the baseband, but also the radio. Going beyond and coexisting with a C-RAN

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foundation, pooled and shared RF and spectrum resources become accessible to all in a dynamic, self-adapting RF distribution system.

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