INTRODUCING RF ROUTERS

INTELLIGENT MOBILE NETWORK CAPACITY AND COVERAGE SOLUTIONS

Dali Wireless | Whitepaper | June 2014

Introduction

The practice of providing wireless coverage in venues is almost as old as the mobile industry itself. Earlier, the goal was to provision venues with sufficient voice capacity. However, there has been a shift in recent years that has stimulated innovations for in-venue communications. The catalyst for this shift is the explosive demand for mobile data services, which have grown by 70% in 2013 to reach 2,000 petabytes[1] per month[2]. To put this into perspective, the volume of mobile data traffic exceeded that of voice for the first time at the end of 2009 when traffic was running at about 100 petabyte per month. By 2018, mobile data traffic volume is expected to surpass 15,000 petabyte per month [2]. But one needs to look further into the areas where demand is generated to understand the urgency: up to 90% of mobile traffic is generated indoors from the confines of offices, public venues such as airports, railway stations, convention centers and homes.

Servicing high-traffic venues with dedicated wireless infrastructure is a sure path to offload congested macro cells which, in turn, has a positive impact on mobile network operators (MNOs). Providing satisfactory mobile data service performance indoors is particularly challenging because of wall penetration losses, high user density and/or traffic volumes. What was required for voice traffic does not map at all to data traffic where the transmission rate is much higher and consequently the requirements for signal quality are much more stringent. For instance, a voice call requires 12 kbps in GSM with full rate codec. An acceptable user experience for mobile web browsing even for the relatively small screen size requires data rates beyond the 1 Mbps mark for downlink speed.

To address the demand for in-venue communications, the wireless ecosystem has developed to offer a number of options that include passive and active DAS systems, small cells, and Wi-Fi access points. These systems approach the in-venue market from different perspectives as we shall explore in the following sections. The low-hanging fruit for operator-deployed systems would be the largest of venues that have high subscriber density and high demand for wireless services. This market is expected to expand as solutions reach smaller venues (Figure 1). Hence, shipments for in-building mobile radio nodes[3] are expected to triple to about 15 million units in 2018 from about 5 million units in 2013[4]. The in-building equipment market is expected to reach $10 billion in 2018, the bulk of which will be DAS and small cell solutions. Enterprises, which today contribute very little capital for mobile infrastructure, are expected to spend $500 million for in-building enterprise infrastructure comprising DAS, small cells and repeaters.

1 For perspective, 1 petabyte of average MP3-encoded song would require 2,000 years to play at download speed of 1 Mbps.

2 Interim Ericsson Mobility Report, February 2014.

3 Remote radio nodes comprise DAS remote modules, remote radio heads and small cells.

4 Source: Mobile Experts.

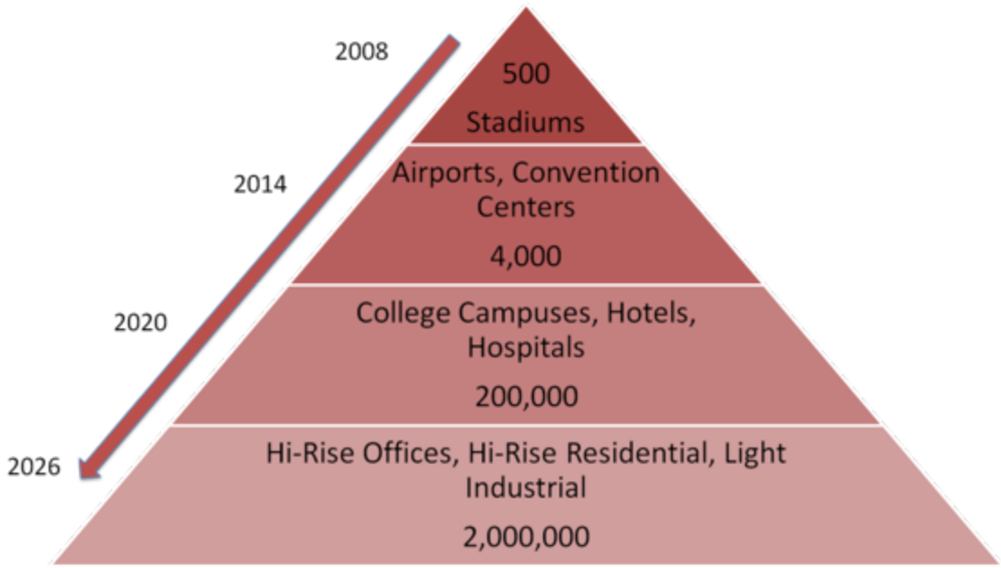

Figure 1: Progression of deployments of in-building communication systems [Source: Mobile Experts]

Options for In-Venue Communications

Today, mobile network operators have more options than ever before for the means of providing service to their subscribers. The macro cell is still the workhorse in radio access networks. Operators have perfected the process of rolling out macro cells which is essential to scale the coverage of the wireless network. However, the consensus is that the macro cell network alone will not be able to meet the future volume in mobile traffic– in many markets, deploying macro cells is becoming increasingly difficult and in some places next to impossible. The public, communities, even legislation is restricting the possibilities of deploying macro cells which has become a challenging, expensive and time consuming activity. Network densification – which entails increasing capacity by adding more cells – is a process already underway as operators seek to lighten the traffic load on congested macro cells through a targeted deployment approach of different RF distribution solutions that include small cells, distributed antenna systems (DAS), and distributed radio systems (DRS), and low cost access technologies such as Wi-Fi. Each of these solutions has specific characteristics and economics that make it favorable for certain use cases which we review below.

Small Cells

Small cells are base stations that combine baseband processing with the radio subsystem in a single compact enclosure of small size that is a few liters in volume (Figure 2). They are also characterized by relatively low RF output power[5] that ranges between 0.2 – 0.5 W for indoor versions and up to 5 W for outdoor versions. Small cells can be deployed indoors in enterprises or homes to provide service to a limited number of subscribers such as up to 8 in residential applications and up to 32 simultaneous users in enterprise applications. They can also be deployed outdoors on poles or other structures at low elevation to serve a specific perimeter that is typically on the order of tens of meters in dense urban areas, or higher in suburban areas. The small cell node is operated by a single MNO in specific licensed frequency bands. Small cells typically feature single or dual technologies such as UMTS, LTE and/or Wi-Fi. The requirement for small enclosure and low power consumption typically limits the ability of small cells to operate on one or two RF carriers. The capacity varies from tens of subscribers for an enterprise-class small cell to a couple of hundred subscribers in outdoor, operator-deployed small cells.

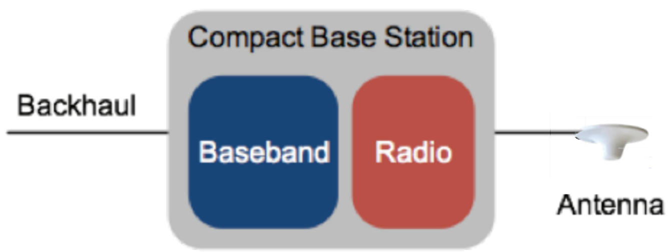

Figure 2: Block diagram for a compact base station ("small cell").

There are different architectural variants for small cell deployments. In one architecture, small cells are connected directly to the core network of mobile operators just as a macro cell would be connected. In another architecture (aka "femto-cells"), small cells are connected to a gateway dedicated to handle access to the network through authentication, security and other functions, which is mandatory if the cells are connected via the public internet as opposed to a MNO-owned trusted backhaul network. Operator-deployed small cells typically follow the first architecture, while user deployed small cells (in the home) follow the second architecture.

The deployment of small cells in indoor venues is targeted at relatively small venues: SMEs, enterprises, and venues where typically the size is small (for example, sub 50,000 sq. ft.). The characteristics of the small cell architectures outlined above typically make it uneconomical or not practical to deploy them in large venues where service from multiple MNOs is required. Moreover, small cells are subject to interference from other small cells or from a nearby macro cell.

5 RF output power in this paper is reference to the antenna port of the base station.

Specifically, the interference between a macro cell and a small cell is mainly due to the large difference of 20-30dB in the system gain, which leads to a reduction of the link budget on the small cell's downlink path. The pathloss imbalance results in uplink interference at the small cell from subscribers at its cell edge that are connected to the macro cell, and in downlink interference from the macro cell to users on the edge of the small cell, and vice versa. Sophisticated techniques (eICIC) have been introduced in LTE Release 10 and 11 to mitigate this problem through carrier aggregation in frequency-domain and Almost Blank Subframe (ABS) techniques in the time domain. Coordinated multipoint (CoMP) where the mobile subscribers are connected simultaneously with two base stations is yet another technique introduced by 3GPP in Release 11 to reduce interference. The probability of self-interference and the complexity of mitigating this increases with number and density of small cells deployed within a given service area.

All these techniques require considerable processing power on both the small cell and the handset; they reduce battery lifetime on the handsets, reduce available radio resources for net user throughput and most importantly, have been invented for the sole purpose of mitigating problems that could be easily avoided – with simpler, yet more intelligent radio distribution methods on which we will elaborate further in the course of this paper.

Distributed Antenna Systems

As implied by the name, distributed antenna systems (DAS) feature multiple antennas fed by a network of coaxial cables that connect to a number of base station transceivers whose signals are passively combined onto the coaxial cables. This is the first generation of DAS, commonly referred to as "passive DAS" (Figure 3). The vast majority of worldwide DAS deployments to date have been of this type. Passive DAS is suitable for small venues and competes with small cells as a coverage solution. The losses in coaxial cables, splitters and combiners are too large for this system to be effective in large venues. Cable losses also increase with frequency, which makes it difficult for these systems to support the new frequency bands released in recent years. It can be hard to upgrade passive DAS systems as more bands and frequency channels become available, passive systems are liable to suffer from passive intermodulation (PIM), which results from combining different frequencies in analog systems. LTE in turn has pushed the signal quality requirements higher for demodulation of high-order modulation schemes such as 64QAM, which further reduces the utility of passive DAS. These factors combined pave the way for active DAS systems that address these limitations.

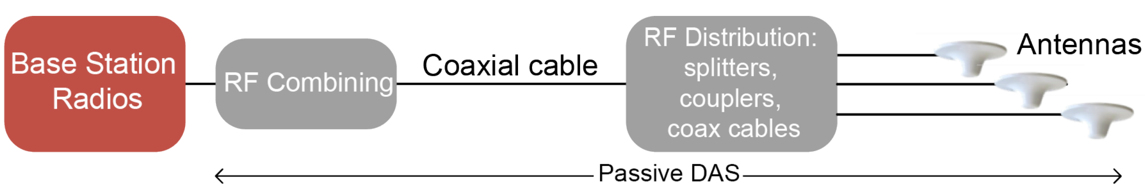

Figure 3: Passive DAS.

Active DAS systems introduce active amplifiers at the far end, i.e. the antenna location to avoid the heavy losses introduced by passive cabling systems. At the head-end, RF signals are converted to optical signals and transported over nearly loss-less fiber across relatively large distances that range between hundreds of meters and a few kilometers (Figure 4). Hence, for the downlink path, the base station transmit signals are first conditioned, combined, and fed into a DAS master unit that converts RF signals into a low-power optical signal which is transported over fiber optical cable to a remote module which performs the opposite operation and transforms the optical signal to RF signals which are amplified and transmitted by a radio subsystem. The power output of the remote radio subsystem is an important element in the design and planning of DAS systems. Typically, the DAS remote radio RF output power can be high – on the order of 20 W (43dBm); medium–on the order of 1 W (30 dBm); or low – on the order of 100 mW (20 dBm). The distance over which optical signals can be transported is determined by the fiber optical link loss budget which is a function of the type and quality of the optical transmitter and receiver.

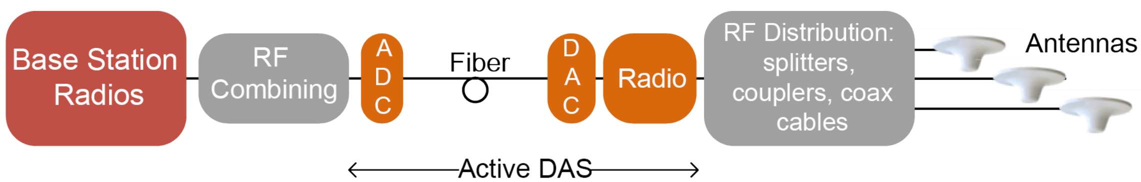

Figure 4: Active DAS.

Most active DAS systems implement an analog modulation process of the optical signal and require two fiber cables, or wavelengths ("colors"), per optical signal: one each for the downlink and uplink path. More importantly, active DAS systems feature a 1:1 relationship between the master unit and the remote unit: optical signals from a single master unit port are transported to a single remote unit where they are reconverted to RF signals. In other words, active DAS are point-to-point systems which require a dedicated optical connectivity between the master unit and every remote radio.

Active DAS systems are generally deployed in large venues that typically exceed 200,000 sq. ft. in size: examples include airports and train stations, underground transport systems, stadiums, convention centers, large office towers, large entertainment complexes and corporate campuses. In such deployments, multiple macro base stations ("BS Hotel") are placed on the head-end of the location to connect to the active DAS system. The remote radio units are placed close to where service is required. Often, high RF power remote units are used to feed a network of coaxial cables, although this practice is gradually phased out in favor of medium-power radio units. Deciding on the number, power capabilities, and placement of the remote radios is part of the design process which has to balance coverage and capacity requirements against cost with consideration of future requirements, as the design cannot be changed easily after deployment to adapt to changing needs in capacity or supported frequency bands.

Distributed Radio Systems

DRSs feature low power remote radios connected to a macro base station either directly through a fiber optical interface running a proprietary or more recently also the standardized CPRI protocol (Type 1). Alternatively, an on-site interface module can be used that allows connectivity over CAT-type cables by converting CPRI to IF signals (Type 2) (Figure 5). DRSs are single operator systems and they are an extension of the macro base station architecture to support low power radios. They allow for close coordination between the overlay macro cell and the distributed radio system, which makes planning, configuration and management easier than with small cells. On the other hand, similar to small cells, traditional DRSs are limited to support a few access technologies and frequency bands in the remote radio. In DRSs of Type 2, the RF bandwidth that can be carried over the CAT5 copper cable connecting the remote radio to the interface module is limited to a few tens of MHz only, with a maximum distance of approximately 200 meter. In all, these types of systems are targeted at medium sized venues, and require presence of fiber on site for connectivity to the macro cell.

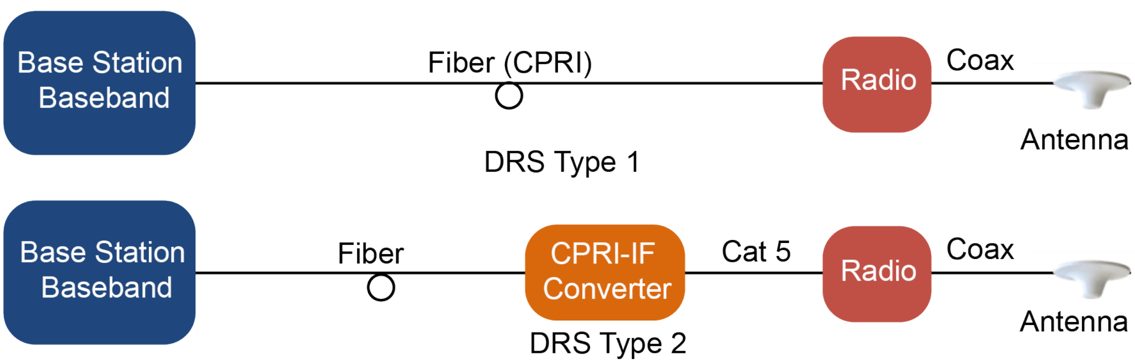

Figure 5: Distributed Radio System: Type 1 is CPRI over fiber to remote radio; Type 2 uses a converter module to connect to remote radio over a Cat5 cable.

Wi-Fi

Globally, 45% of total mobile data traffic was offloaded through Wi-Fi in 2013. This is projected to increase to 52% of total mobile traffic in 2018[6]. Wi-Fi offload takes place primarily in indoor locations (Figure 6). Subscriber satisfaction with Wi-Fi offload is higher at home and in offices than in large venues where it becomes more challenging for Wi-Fi to deliver on the expected quality of service because of its inherent technology characteristics such as unlicensed band, contention-based medium access control layer, lack of QoS over the air interface as opposed to the capabilities provided by access technologies such as LTE. On the other hand, Wi-Fi devices benefit from mass deployment and economies of scale such that the cost to carry 1 MB of data over a cellular network is 10x the cost of carrying it on Wi-Fi.

6 Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018.

The proliferation of Wi-Fi as an offloading technique for data services has led to the need to harmonize with operator-deployed RF distribution systems that offer voice service in addition to high-SLA data services which Wi-Fi by its nature cannot scale to achieve. This is reinforced with industry activities to improve the integration of Wi-Fi with the radio access network by minimizing human interaction related to Wi-Fi selection, authentication and service activation through technologies such as Passpoint. This is based on the Hotspot 2.0 specifications that are designed to improve access to the Wi-Fi network through the mobile SIM. Wi-Fi offloading also implies that all handsets will natively support Wi-Fi operation, which today is practically the case, but not necessarily a given fact.

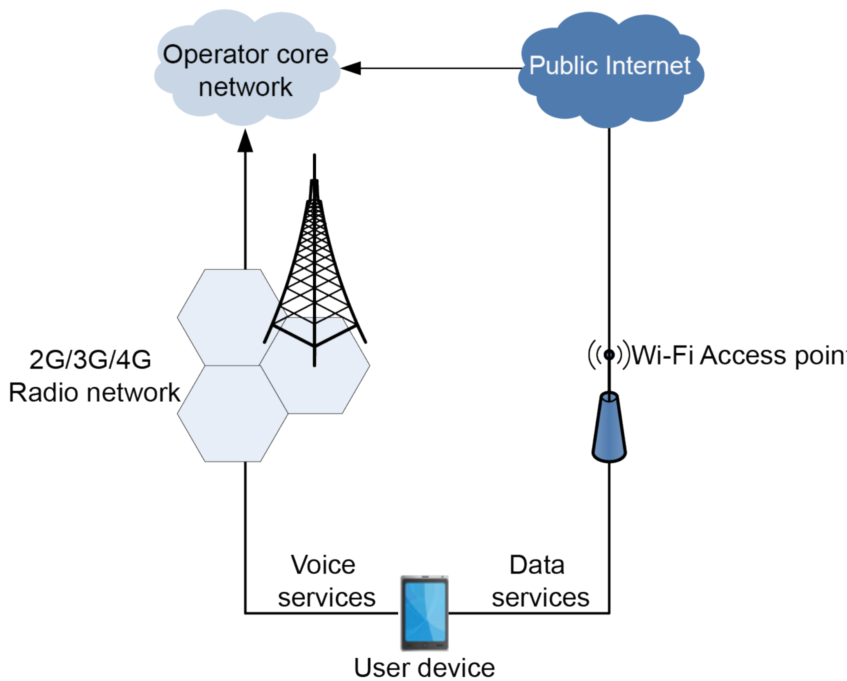

Figure 6: Wi-Fi Offload concept.

RF Routing – A New Approach in RF Distribution

Providing wireless services in large and small venues led to the development of different solutions and technologies as outlined above. Each has distinct characteristics that make it attractive for a certain use case. For instance, Wi-Fi is low cost but its performance suffers with scalability. Small cells are good at adding capacity in single operator deployments but they fall short on scaling in multi-operator, large-venue deployments because of interference. In the meantime, active DAS systems are good for multi-operator deployments but are limited in scaling to supply capacity where it is needed because of the point-to-point association between the master unit and remote radio.

To achieve greater utility and cost efficiency for venues, Dali Wireless has developed a solution that virtualizes the radio access network through a router that transforms the RF distribution from an analog-based point-to-point network into a digital multipoint-to-multipoint network. The system functions as a router of RF signals over primarily fiber optical cables[7] where signals from any base station antenna port can be routed to any connected remote radio. The system incorporates a portfolio of patented technologies worldwide that is fundamental to the underlying virtualized RAN architecture. This revolutionary platform enables differentiating features such as flexible simulcast operation and capacity routing. In this, a new class of RF distribution systems is now available to meet the evolutionary trends in the in-venue market for both, indoor and outdoor usage, which include the following requirements:

1. Accommodate multiple spectrum bands, multiple access technologies, and multiple network operators.
2. Offer high scalability and flexibility to quickly grow the distribution system on-demand as new technologies and spectrum become available.
3. Provide capacity instantaneously when and where it is needed. This transforms the RF distribution network from a static configuration to a dynamic capacity solution and reduces total cost of ownership by allowing the capacity of pooled base station resources to be directed where and when it is needed in a fully software-controlled manner without the need for human intervention on site or any cable reconfiguration.
4. Support different business models that include operator infrastructure sharing, third-party neutral hosting, and capacity or coverage as a service based on pay-per-use business model.
5. Allow each operator to independently manage and control the parameters of their RF resources independent of other operators.
6. Allow Wi-Fi access points and small cells to leverage the optical distribution network for backhaul and reduce the cost of deploying these offload technologies.
7. Future-proof operation capable of supporting new wireless technologies.
8. Provide low cost of ownership in all aspects of the business case.

With the above features in place, Dali's RF Router™ solution adds new use cases and enables new deployment scenarios for high utilization of base station resources and spectrum assets.

7 Gbit microwave and CAT5E or higher can be used as the case requires.

RF Routing Solution

The fundamental principle behind the RF Router is the end-to-end digital signal processing, which provides flexibility in how RF signals from the base station are distributed and re-generated at any of a number of remote radio modules (Figure 7). The analog RF to digital conversion occurs in a signal processing module (tHost) that connects to the antenna port of the base station. The digital signal is tagged with an address, which allows routing it to any connected remote radio, similar to routing of an IP packet. RF carriers in multiple bands can be aggregated to over 300 MHz of digitized RF spectrum segments within a single module. The aggregated digital RF signal is converted to an optical signal and transported over the fiber at a rate of 10 Gbps. A single optical transceiver is used which requires a single fiber to carry both the downlink and uplink signals. This reduces the number of fibers, the length of fiber runs used by the system and reduces cost of deployment and operation. The fiber cable connects to one or more remote radios that support up to four RF bands and 75 MHz of utilized RF spectrum each. Multiple versions of the radio unit are available to provide different combinations of frequencies and output RF power. The t30 model provides 1W per band or 20 W per band for the t43 model. Digital pre-distortion and crest factor reduction techniques are implemented on the remote radios to maximize efficiency, improve amplifier linearity to within the specifications of the access technology, and reduce power consumption. The modular concept of the radio units allows to combine any four of the supported RF bands in a single t30 radio unit, including multiple RF modules operating on the same band, e.g. for MIMO deployments. All US-bands and the European/Asian bands for GSM, UMTS and LTE as defined by 3GPP are supported.

It is important to note that digital signals such as Ethernet and CPRI can also be transported between the RF Router and the remote unit. The digital operation mode enables routing of signals between one or more RF Router units and multiple remote radio nodes, in essence a multipoint-to-multipoint connectivity. Any RF carrier from any base station sector can be routed by the RF Router unit (tHost) to any – one or more – remote radio modules over long distances that far exceed what is possible in analog optical systems. Hence, RF routing operates in a wide-area mode that provides added flexibility in primarily coverage-limited deployment scenarios.

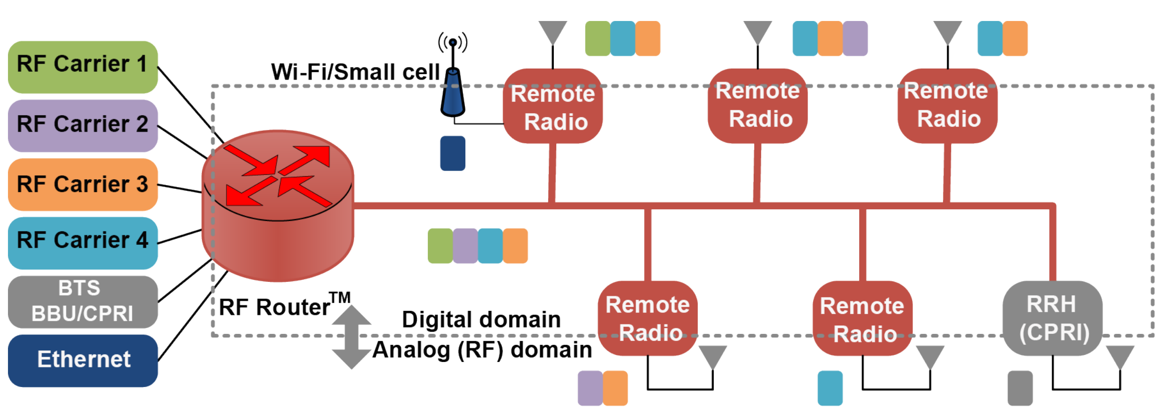

Figure 7: Block diagram for Dali's RF Router.

Multipoint-to-Multipoint Operation

The transformation of RF distribution from an analog, point-to-point architecture to a digital, multipoint-to-multipoint topology enables dynamic allocation of capacity to where and when it is needed. This is a critical feature as utilization of radio resources varies with time and location. For example, it is possible to know in advance when a large venue such as stadiums and convention centers would see high traffic and to target more capacity to that venue and at that time from a central pool of base stations. Furthermore, it is possible to see variations in traffic distribution within a venue over time. Multipoint-to-multipoint operation eliminates the need to provision every end-node with the peak capacity, which reduces the requirements for number of required base station resources: capacity can be routed to where it is required at the time when it is required. This in turn reduces both capital and operational expenditures.

A second benefit to multipoint operation is simulcast. Simulcast involves synchronous transmitting and receiving the same signal from multiple remote radios. For this, it is necessary that remote radios are tightly synchronized with low jitter. Technology implemented in the Dali solution allows digital compensation for signal propagation delay down to 32 nsec of precision which exceeds the requirement by 3GPP for LTE MIMO operations by a factor of 2.

The handling of MIMO signals has been problematic in traditional DAS systems because MIMO performance is sensitive to phase synchronization and balanced power between the signal branches. Dali's simulcasting, power control and time synchronization capabilities effectively address and resolve these issues, making the Dali RF Router solution the only known system on the market today which meets and exceeds the 3GPP requirements for MIMO operations.

Single Logical Cell

The Dali RF Router solution allows combining multiple individual RF footprints of the connected radio cells to a single logical cell towards the macro network management system. The footprint and capacity allocation of this logical cell is dynamically configurable by software control, thus representing a virtualized radio access network. The cell formed by the Dali system appears to the macro network as a single logical cell, thereby removing the need for handover between the individual RF footprints and removing the complexity of configuration and performance management for multiple small cells. This also reduces the signaling load in the network, frees up processing power in the NodeB's and increases the amount of RF resources available for net user data, which in turn directly translates to a better user experience.

Long Range

The ability to carry optical signals over a long range, as far as 40 km, is the result of up to 20 dB optical link budget that allows operators to enact new deployment scenarios such as base station hosting. For instance, the base station can be deployed in a fiber center far from the venue where the remote radio modules will be located and distributed to meet the performance objectives. This scenario enables operators with fiber assets to save on deployment costs by limiting the assets placed on remote locations. It also allows operators to serve areas where space for base stations is not available or where low subscriber density does not justify placing dedicated base stations, e.g. along railway tracks.

Infrastructure Sharing

In order to reduce the total cost of ownership, operators can share in-venue systems where base stations of multiple operators connect to a single RF distribution network. The digital architecture allows the greatest scalability in a multi-operator, multi-frequency deployment as each operator has fully independent control of the power budget of their corresponding RF carriers in addition to the distribution of the capacity of the carriers across the available end points. Combining signals in the digital domain limits PIM products which plagues traditional DAS systems in multi-operator, multi-carrier deployment scenarios. Moreover, it enables a technology agnostic solution that facilitates on-demand upgrades in access technology. The capabilities of the RF Router architecture and its benefits enables new business models in infrastructure sharing such as neutral hosting by third parties.

Wi-Fi & Small Cell Integration

We have described earlier how Wi-Fi complements the wireless network particularly in indoor venues where it is used to offload mobile data traffic. Thus, it is advantageous to integrate Wi-Fi services with the RF distribution network to reduce the cost of Wi-Fi deployment. This specifically applies to the backhaul of Wi-Fi access points. Dali's RF Router provides a multi-purpose 1 Gbps transparent Ethernet channel on each fiber link to/from the tHost unit. This channel can be used to carry IP traffic of Wi-Fi access points, other IP appliances e.g. webcams or announcement systems as well as small cells, as required.

RF Routing represents a breakthrough in the evolution of RF distribution networks to address the needs of operators as they strive to meet the requirements for ubiquitous service which encompass data services that have high requirements on data rate in comparison to the low-rate voice services.

	Conventional active DAS	Dali RF Router
Typical use scenario	Coverage extension	Intelligent RF and capacity routing intelligent coverage as well
Architecture	3-tier network (Master, Distribution, Radio)	2-tier network (tHost, Radio)
TCO level	High	40% lower (typical)
Signal processing	Analog	All-digital
Transmission	Noise limited	low-noise optical
Capacity management	(none)	Individual capacity allocation per remote unit
Configurable coverage	(none)	Dali Smart Cell concept
EMS/NMS solution	Mostly not available	EMS embedded in every unit, web-based NMS
Wi-Fi integration	(none)	Integrated 1 Gbps IP link on every fiber link
Topology	Star network only	Star, chain, hybrid, loop
Size & weight	50 ltr / 40 – 80 kg (4-bands)	20 ltr / 14 kg (4-band radio unit)
Power consumption	Typically 500 – 800 W per radio	120 W (4 bands, t30)

Table 1 Comparative analysis between active DAS and Dali RF Router.

Additional Benefits

Using small cells to provide capacity in an area with high traffic and user density results in a high number of handovers since the cell size is intentionally small to increase spatial reuse. In addition to interference, this has a negative impact on network performance and effectively reduces the usable capacity and creates a high amount of signaling load in the network due to session re-establishment and mobility handling. The RF Router enables high precision simulcast and achieves an accuracy of synchronization down to 32 nsec in the time domain for the best handover experience the user can possibly have today. Additionally, the network operator enjoys the advantage of synchronizing different radios automatically with a SON-based approach whereas in traditional solutions all the fiber cables have to be cut to the exact same length and deployed at precisely that length for all remotes, resulting in systematic material waste and additional cost.

Deployment Scenarios

The flexibility provided by the RF Router is a key aspect to achieving the lowest cost of ownership. The all-digital architecture enables multiple network topologies that cater to different deployments scenarios: star, chain, hybrid and loop topologies. In each of these deployments, the digital technology allows each remote radio to be assigned to a single operator or shared between multiple operators.

Star Topology

This is the simplest and most commonly used topology by any other traditional system. In this topology, each of the remote radios is connected to the RF Router unit through a single optical cable (Figure 8). Each of the remote radios can operate on up to four RF bands or technologies. Specific carriers can be activated per remote radio. The star topology provides high connection reliability of the entire system as each radio is individually connected to the RF Router unit.

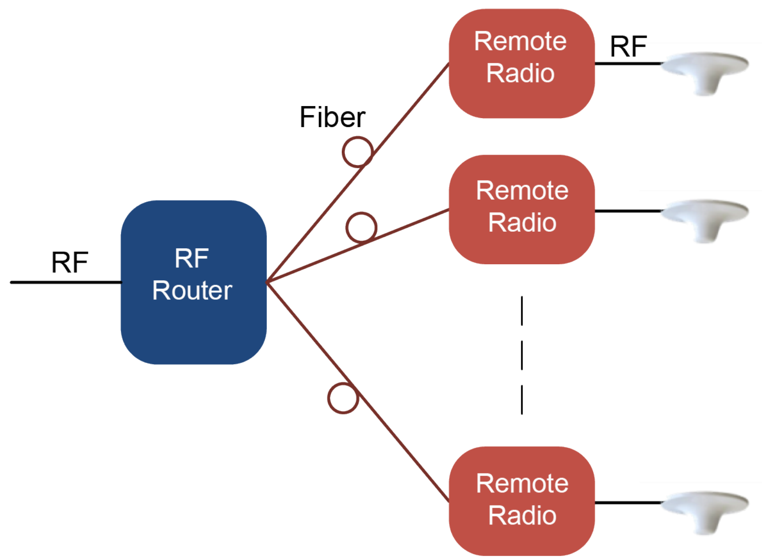

Figure 8: RF Router in star topology.

Chain Topology

In this topology the remote radios are sequentially lined up along a single fiber line ("daisy chain") (Figure 9). Hence, a single fiber cable connects the first remote radio with the master unit and henceforth, a single cable connects a remote radio with the next. The Dali radio units are equipped with a by-pass feature that retains connectivity along the chain in case a remote radio fails. This mode requires less optical fiber cable than the star topology and results in lower deployment and operational cost. Each tHost or radio unit provides 8 fiber ports to support up to 8 connections to/from other single units or chains.

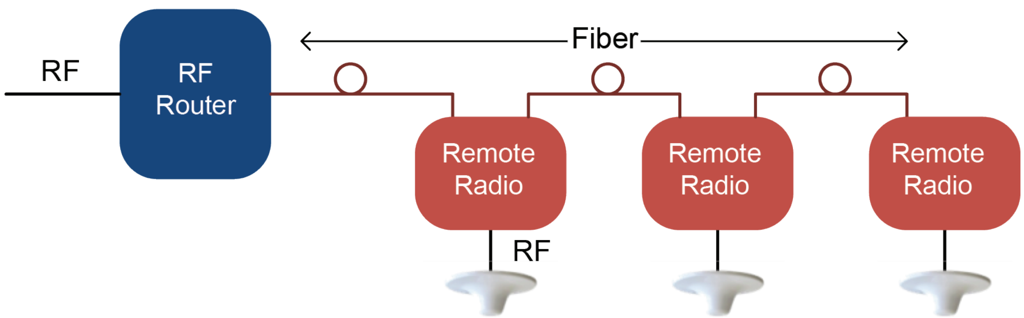

Figure 9: RF Router in chain topology.

Hybrid Topology

The hybrid topology combines the star and chain topologies (Figure 10). 8 fiber ports on the tHost or the radio unit can be used to connect to one single or a chain of remote radios modules.

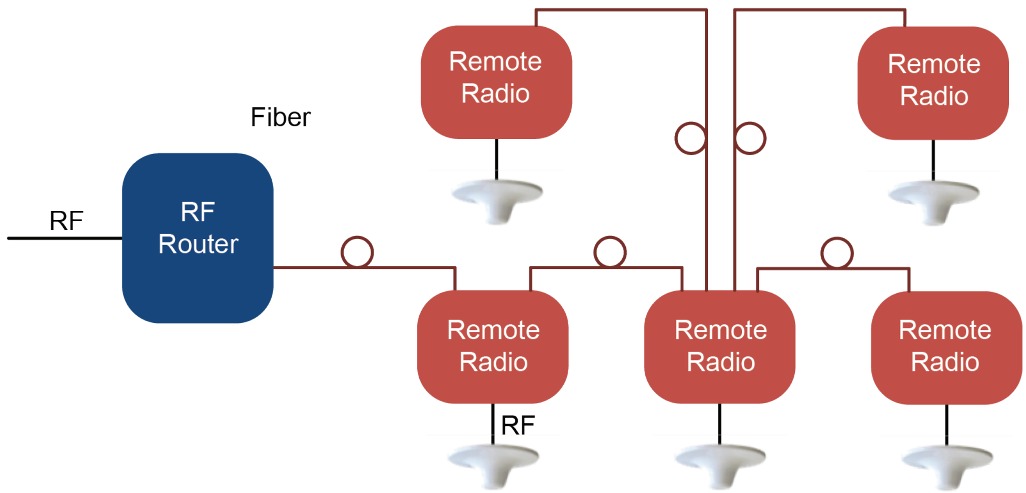

Figure 10: RF Router in hybrid topology.

Loop Topology

The patented loop topology connects the last node of a chain back to the tHost unit (Figure 11). This topology provides an alternative signal path to/from the remote radios in case the primary path is interrupted e.g. by a fiber break or maintenance works.

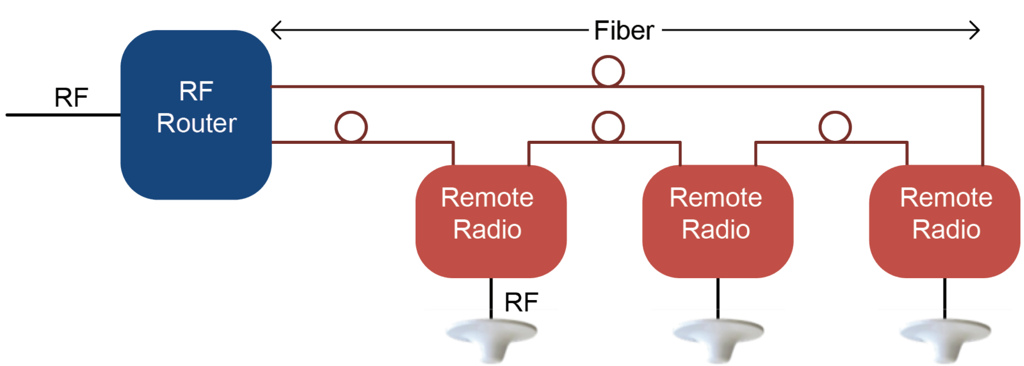

Figure 11: RF Router in loop topology.

Cascading RF Router Modules

The RF Router modules can be cascaded by interconnecting multiple units with fiber optical cable (Figure 12).

This patented option allows true "any-to-any" routing between any RF input of the pooled base station resources as the source and any connected radio unit as the destination. This is a unique feature of the Dali RF Router system and is not provided by any other known system today. Operators can use this mode to scale the number of frequency bands by chaining additional remotes with different bands as well as adding support for public safety bands for emergency services.

This option also allows multiple operators who like to share the distribution network to have an independent RF Router module for operation and management function, or to provide additional frequency bands or sectors to be connected, while the overall deployment and operational cost is minimized by sharing fiber and remote radios.

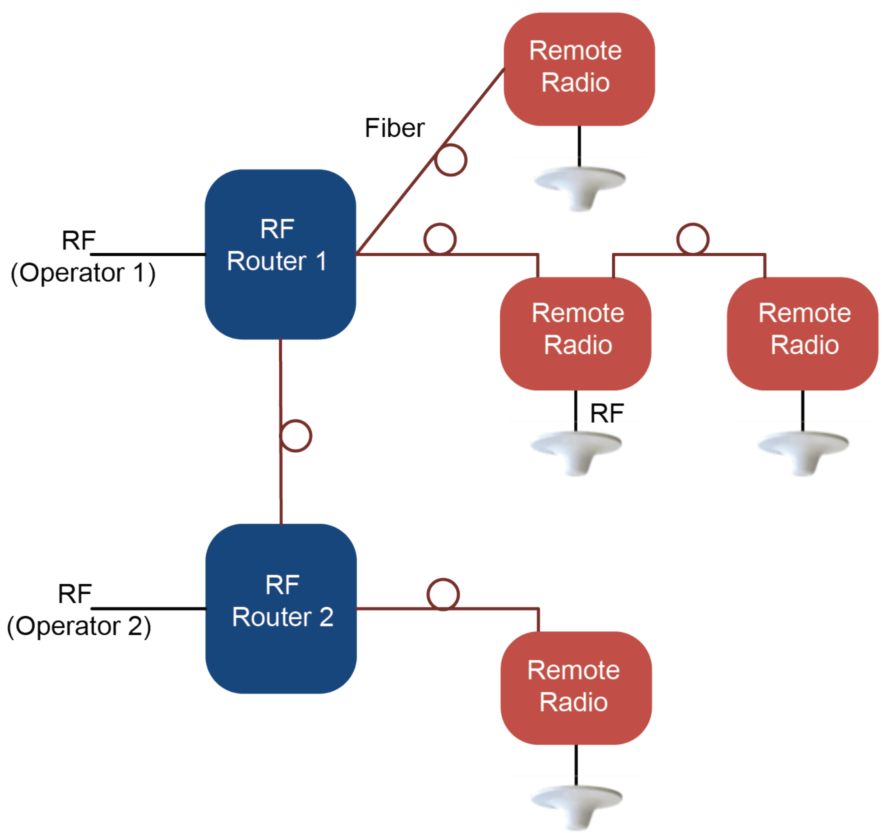

Figure 12: Cascaded RF Router Units with a hybrid topology.

Capacity Routing

The all-digital technology of the RF Router fundamentally changes the approach to delivery of mobile services in high-traffic venues, indoor or outdoor. The ability to route any source of centralized capacity to any destination in the RF distribution network where and when it is required reduces the capital and operational cost of the deployment. It also increases the utilization of base station resources and spectrum assets. Fewer base stations are required to service a venue because it is now possible to dynamically allocate wireless capacity on demand where and when it is needed. This obviates the need to design for peak capacity at every single node (or service area) where excess capacity sits idle for most of time. Instead, the network is provisioned for the aggregate capacity required at the service area.

As an example, consider a stadium and its parking lot. Before the game starts, traffic through the parking lot builds up gradually. Spectators move into the stadium through large alleys and hallways to take their seats. Mobile traffic would be higher in such areas before the game starts than inside the stadium. As the game starts, traffic shoots up from within the stadium around major events during the course of the game. When the game finishes, traffic increases in the parking lot and decreases in the stadium. While traditional systems would need to allocate peak capacity from wireless base stations to both, the parking lot and the stadium in a static way, the RF router only requires capacity to meet the aggregated demand of the entire venue. This capacity is switched automatically and remotely from the NMS before and after the game to the serve the entire venue, as needed.

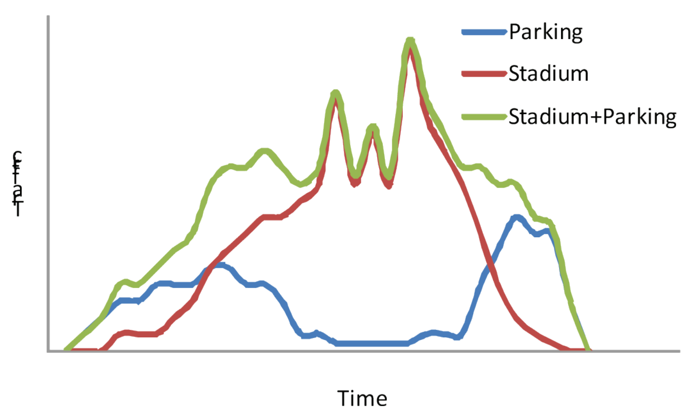

Figure 13: Traffic distribution in a stadium complex.

There are many applications for the RF Router that leverage temporal variations in traffic distribution in a network. Consider, for example, a passenger train, which is effectively a traveling capacity hotspot. The RF Router allows placing N remote nodes along-side the track with central base station resources C that meet the capacity requirements of the passengers on the train. Without the RF Router, the need would be to provision every node with capacity C for a total of N x C, which is a significant cost increase.

Conclusions

Localization of mobile data consumption indoors presents a multi-faceted challenge for mobile network operators. Traditional solutions that have performed well in a voice-centric network fail to effectively provide the desired quality of service, either of the capacity or the coverage, in a data-centric network. New bands in higher frequency spectrum coupled with operator requirements for access technology neutrality and the requirements for LTE technology for high signal quality to enable efficient broadband services through MIMO and spectrally efficient modulation add to the technical and economic challenge. These, alongside other trends, have led to the development of a new breed of in-venue solutions represented by the RF Router.

The RF Router represents a breakthrough in distributing RF signals. It effectively couples a capacity and coverage solution by converting analog RF signals into digital packets of spectrum segments that can be routed to one or more remote modules, where the signals are converted back to the analog domain to be transmitted over the air. This provides several advantages which include capacity switching between a central pool of baseband processors to different service areas per demand requirements, simulcast of signals by several remote radios, and long range extension of RF service to areas that are uneconomical to reach with traditional wireless coverage solutions. Such features are especially important in venues where traffic reaches very high levels over a limited period of time and demand is low for significant parts of the day.

The RF Router increases efficiency by achieving a high utilization of base station resources and spectrum. Additionally, the increased utility of the solution provides network operators with lower capital and operational cost than those of traditional solutions or new 3GPP Rel 10 and 11 features such as e-ICIC and CoMP which are not widely deployed yet.

Acronyms

3GPP	Third Generation Partnership Project
ABS	Almost blank sub-frame
BS	Base station
CAT5	Category 5
CPRI	Common public radio interface
DAS	Distributed antenna system
DRS	Distributed radio system
eICIC	Enhanced intercell interference coordination
EMS	Element management system
IF	Intermediate frequency
IP	Internet protocol
LTE	Long term evolution
MIMO	Multiple input multiple output
MNO	Mobile network operator
NMS	Network management system
PIM	Passive intermodulation
QAM	Quadrature amplitude modulation
QoS	Quality of service
RF	Radio frequency
RRH	Remote radio head
SIM	Subscriber identity module
SLA	Service level agreement
SME	Small medium enterprise
TCO	Total cost of ownership
UMTS	Universal Mobile Telecommunication System

About Dali Wireless

Founded in 2006, Dali Wireless is a global provider of an all-digital RF Router, a new concept which transcends the features typically associated with traditional Distributed Antenna Systems (DAS) to deliver more data throughput and value at a lowest Total Cost of Ownership. With its patented dynamic capacity allocation technology, mobile operators and enterprises can dynamically allocate capacity to where and when it is needed. This is achieved through Dali's proprietary signal processing algorithms that transform any radio signal into addressable frames/ data packets, enabling Radio Distribution Network (RDN) of "any-to-any" connections between sources and destination points– a software defined network. This unique architecture allows on-demand routing of radio capacity utilizing flexible simulcast ratio to avoid challenges associated with conventional RAN architecture: link budget, interference and handovers. The Dali RF Router can improve useable capacity by over 20 percent as compared to conventional small cells.

Dali WIRELESS®

www.daliwireless..com