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SDN PROGRAMMABLE CONTROL ON THE MOBILE EDGE

Six Design Principles for SDN Solutions in Mobile Backhaul

Mobile services and mobile backhaul networks are under pressure from a variety of technology, market, and financial forces. Fortunately, SDN can help meet the challenge of creating the more dynamic, application-aware backhaul network of the future. The separation of control/forwarding planes, centralization of critical control plane functions, and open APIs inherent in SDN promise substantial benefits.

HIGH IMPACT APPLICATIONS FOR SDN

Looking beyond the traditional data center application of SDN, high impact applications for this new technology in the challenging mobile backhaul (MBH) network environment include:

- Automated S1 interface provisioning, re-homing, and optimization
- Improved network utilization
- High reliability, high performance services
- Network support for distributed virtual gateways
- Self-organizing and multi-layer networking

SIX DESIGN PRINCIPLES FOR MBH NETWORKS

Network planners responsible for MBH networks should consider six design principles when comparing potential SDN solutions:

1. Scalable, high availability controllers
2. Flexible control options
3. Open programming APIs
4. Hybrid network support
5. Robust network management
6. High performance network elements

SDN promises network efficiencies and compelling new services. However, access networks, such as MBH networks, place unique demands on potential SDN solutions that must be factored into carrier deployment plans.

THE DEMAND FOR SDN IN MOBILE BACKHAUL

SDN is one of the most notable new developments in carrier networks. Offering the prospect of the network as a programmable resource configured on demand, SDN has the power to change how services will be delivered in the future. Carriers worldwide are eagerly investigating how software-defined services can bring new revenue, streamline network maintenance, and automate service creation.

The leading applications for SDN-enabled services have been:

- Within the data center to support complex service chaining
- Between data centers to optimize core network utilization
- For Ethernet transport services such as bandwidth on demand

Less often discussed is how SDN fits into access and aggregation domains for mobile networks. This is an area of rapid change, as data usage shifts to mobile networks, and MBH networks grow in size and complexity. Not surprisingly, a 2014 Heavy Reading survey of telecom operators commissioned by Coriant pointed to a high degree of interest in deploying SDN in the MBH network.

FIGURE 1 – Expected Timeframes for SDN Deployment in Mobile Backhaul Networks

MOBILE BACKHAUL TRENDS AND CHALLENGES

TODAY'S MOBILE BACKHAUL NETWORKS

Mobile networks evolved over dedicated backhaul links to connect centrally located mobile gateways (BSC, RNC, SGSN) to cell towers. These connections began as TDM links, but in 3G networks (3GPP Release 5 and beyond), they were replaced by higher speed ATM/Ethernet services, and then later replaced with MPLS VPNs and pseudowires over leased or dedicated Ethernet. While legacy MBH services are still in use, the pure packet environment of LTE (3GPP Release 8) is best served by L2/L3 VPNs and Carrier Ethernet supported by underlying optical and microwave transport.

As a result of this evolution, traditional hub-and-spoke mobile networks share some typical characteristics:

- A single or limited variation of macrocells (NodeB) deployed across a provider's coverage region
- Traffic aggregation at central gateway locations
- Network-based synchronization provided as a critical requirement for the Radio Access Network (RAN)
- Bursty network traffic managed by either adding excess capacity or by dropping or queuing traffic

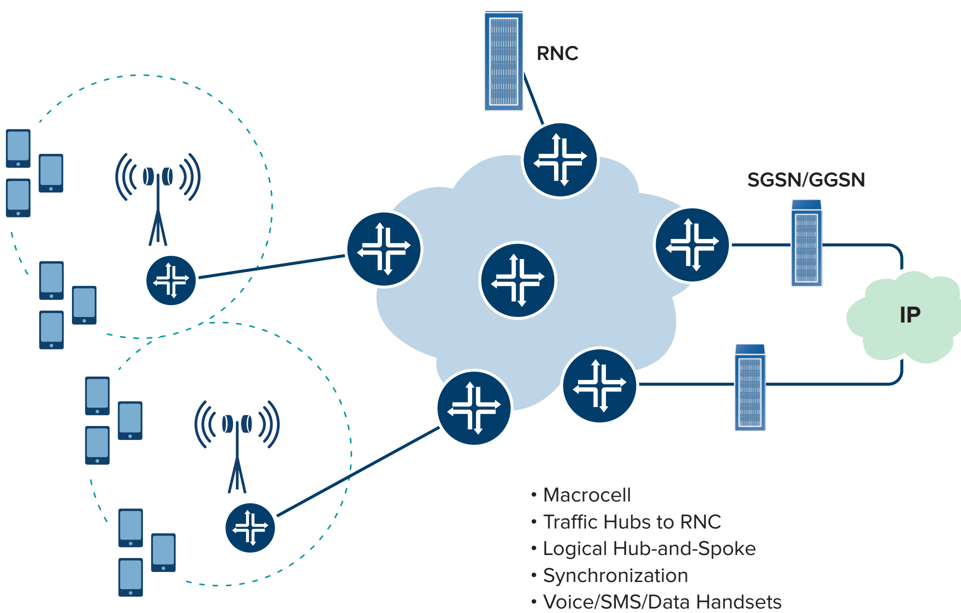

FIGURE 2 – Traditional Hub-and-Spoke Mobile Network Architecture

MOVING TOWARD A DYNAMIC, HETEROGENOUS MBH NETWORK

As new over-the-top (OTT) applications appear with increasing speed, carriers struggle to update network resources on short notice to meet user and application demand. A new generation of applications is far less tolerant of latency and congestion. Traditional smart phone bandwidth demand will continue to grow as streaming media and real time communications extend into new applications. The hierarchical hub-and-spoke design served well in previous generations of mobile voice, SMS, and low speed data, but broadband mobile services now dominate, which places networks under severe stress.

A number of trends point to the need for a less hierarchical and more dynamic user performance-aware backhaul network.

These trends will challenge carriers to transition to a more dynamic and heterogeneous network:

- **LTE-A and 5G Throughput Objectives** – With user throughputs rising to 1G and beyond, it becomes increasingly costly to backhaul all traffic to the network core. Local handoff of best-effort Internet traffic can reduce network costs. But reliability is at risk when all traffic is aggregated on a small number of core links.
- **5G and Internet of Things Performance Objectives** – The GSMA-defined objectives of <1ms latency and always on availability require tighter control of network delay, as well as more robust protection from redundant links extended to the network edge. New Internet of Things (IoT) services for eHealth, remote real time device control, and other performance-sensitive applications will also demand ultra-low latency.
- **Backhaul Network Congestion Control for LTE** – In 3G networks, the RNC acts as a control point in the backhaul network, but in 4G/LTE networks, the RAN relies on the MBH network for all congestion control. As a result, the backhaul network is required to provide application-specific performance.
- **NFV Mobile Gateways** – The advent of virtual EPCs will fundamentally alter the structure of MBH networks. As virtualized gateways are distributed throughout the network, cell sites will no longer need to be anchored to centralized termination points. This trend toward mobile edge computing will require consideration for application performance and location in MBH network design.
- **Internet of Things** – The predicted proliferation of low speed sensor traffic and network-attached devices – also referred to as Machine Type Communications (MTC) or Machine to Machine (M2M) applications – will require low latency and ultra-high reliability connectivity to private monitoring facilities not co-located with traditional mobility gateways. Virtual EPCs may be especially relevant for IoT to provide application-specific scalability and performance.
- **FMC Requirements** – As mobile networks have moved to a pure packet design, they more closely resemble wireline IP networks. It is increasingly common to combine both service types over a converged aggregation network, which demands both higher network capacity and a mesh architecture, since fixed traffic is not necessarily as homed to the traditional aggregation points (RNC, EPC, etc.) as mobile traffic.
- **Higher Density Access Networks** – Serving more users in concentrated areas requires more densely distributed cell sites. The proliferation of pico, femto, and small cells with coverage that overlaps macrocells creates synchronization, radio interference, and overall backhaul capacity challenges. Access links for the new cell sites result in many more network endpoints to manage and a heterogeneous set of nodes that must be synchronized to share spectrum.
- **Flat or Shrinking ARPU** – As data has come to dominate mobile usage, financial pressures have driven mobile network operators toward more efficient network utilization, innovative new services, and more efficient network operations.

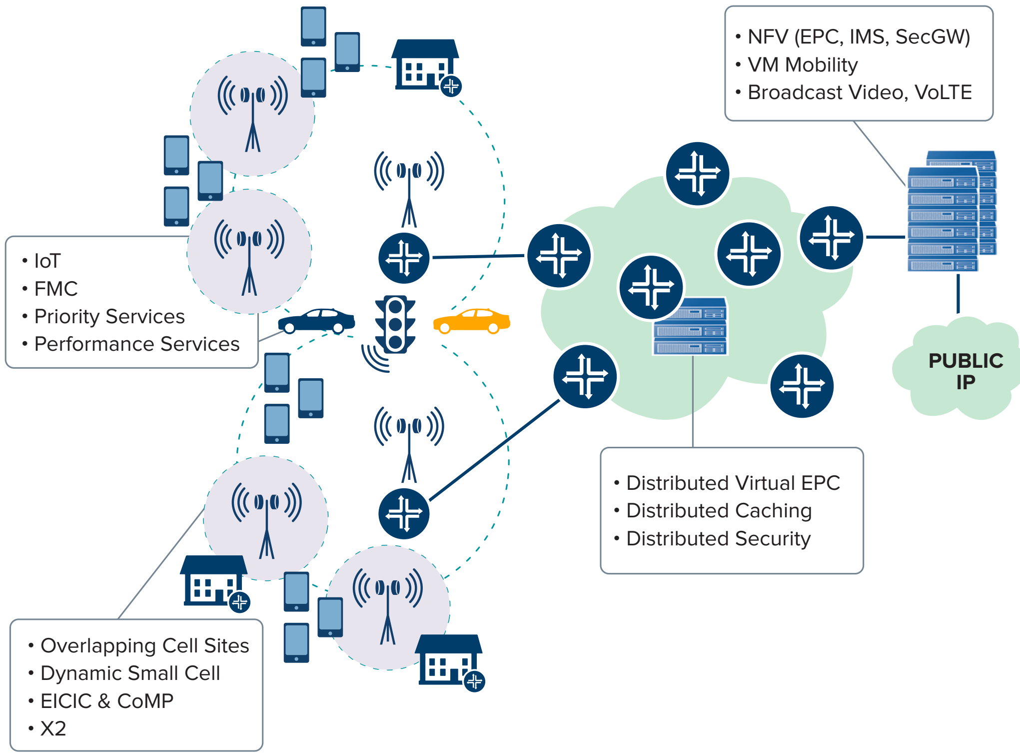

FIGURE 3 – Trends Impacting Next-Generation Mobile Networks

SDN DEFINED

While a few fundamental concepts underpin SDN, there remains a healthy debate in the networking industry about the best way to implement SDN:

- **Separate Control and Forwarding Plane** – While this separation already exists within routers (forwarding decisions are made by different processors than control decisions), SDN extends the concept to running control plane logic on an external controller platform. There are, however, a variety of opinions regarding precisely which functions of the forwarding plane should be separated. To provide a smooth migration for existing networks, an incremental approach, in which a key set of functions like route or tunnel path computation are first migrated to external control, may be warranted.

- **Centralized Critical Control Plane Functions** – While distributed network protocols like Ethernet, IP, and MPLS have supported the expansion of resilient Internet and global communications networks, they also carry limitations:
    - Forwarding decisions are based on a finite set of protocol variables
    - Topology and forwarding state must be shared by all nodes, causing convergence delays
    - Protocol upgrades are complex and affect all network nodes

By performing key functions in a centralized controller, the network opens up to new path computation options and faster upgrades focused only on updating the controller functionality. Nevertheless, packet forwarding decisions for traffic management and resiliency, OAM and performance management, network synchronization, and various other functions remain within distributed network elements (NEs). An ideal SDN architecture will balance these factors and centralize only those functions that benefit from a unified controller.

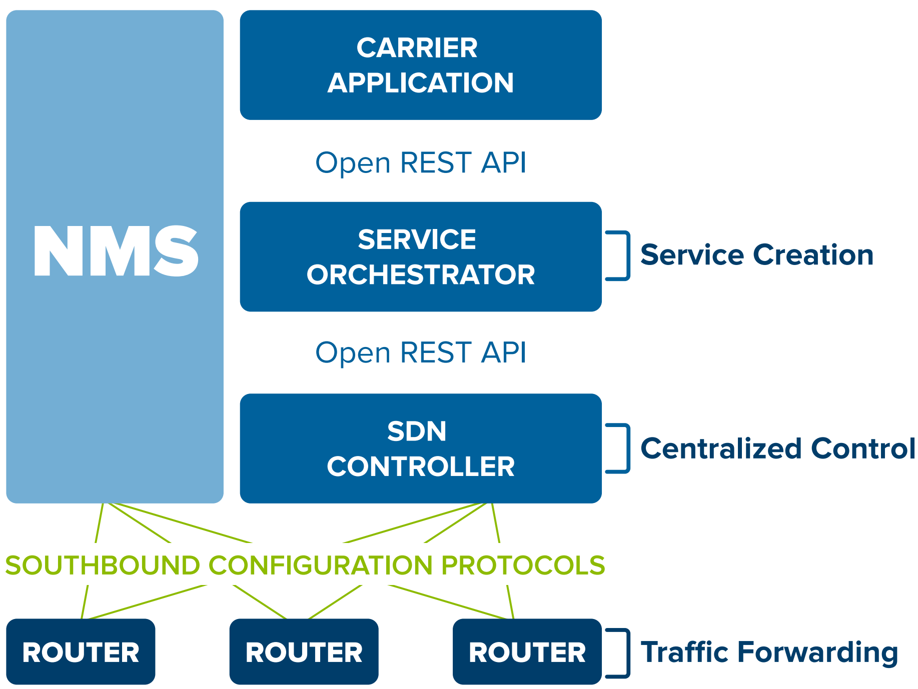

FIGURE 4 – SDN Architecture

- **Open Standard Programming APIs** – To support a wide variety of applications and integrate between multiple vendors, an open library of Application Programming Interfaces (APIs) is required. The API library should not expose all of the complexity of the network, but instead it should present a simplified, abstracted view, so that carrier applications can make high level service requests of the network without knowing path details or hardware configuration protocols. These same APIs can also serve as an interface for service requests and network updates to third party controllers. The evolution of northbound programming APIs and southbound configuration protocols can occur independently, since the controller separates these two domains.

Regardless of the specific implementation, a broad range of new network applications is possible by incorporating these three core SDN concepts.

SDN APPLICATIONS IN MOBILE BACKHAUL NETWORKS

UNIQUE DEMANDS OF MBH NETWORKS

Carrier access and aggregation networks present a substantially different deployment environment than the data centers where SDN was first established. With thousands of NEs widely distributed across a geographic area, the MBH network demands a high performance infrastructure combined with low touch management. Often these devices are located in remote, difficult to access, or harsh operating environments.

Consequently MBH equipment tends to have a long in-service life, with multiple RAN generations coexisting in a typical network. Further complicating matters, a wide range of transport facilities are employed for backhaul, including microwave, copper, and fiber, each with its own transmission characteristics and limitations. As a result, sophisticated QoS or traffic management functions and fast protection at a remote node level require that many packet processing functions take place within the NEs rather than within a centralized controller.

HIGH IMPACT SDN APPLICATIONS

SDN offers design and management options for backhaul networks to meet the challenges of mobile network evolution. The introduction of an external control plane and programming APIs will enhance backhaul network configurability and optimization to improve flexibility and responsiveness. These considerations point to a distinct set of SDN applications for MBH networks.

Automated S1 Interface Provisioning, Re-homing, and Optimization – The S1 interface from cell site to Evolved Packet Core (EPC) is the most fundamental LTE interface. This end-to-end link is generally configured once and left in place.

However, this static deployment model must change in order to accommodate future virtual network designs and IoT services. Small cells, which may be turned on only as needed based on network usage, represent another S1 interface type that would benefit from on demand activation. A more dynamic path control plane can automate S1 activation to virtual gateways or small cells and optimize the S1 path in real time based on network performance, alarms, or congestion from other sites and applications.

Automation tools available today require manual input by network administrators to initiate new service configurations or updates. Frequently, granular service configurations and circuit mappings must be manually input via a command line interface (CLI) or other legacy management protocols (e.g., SNMP). Processes involving multiple configurations and management systems are difficult to adapt to new services and impose long service activation cycles. Optimizing in-production services poses an even greater challenge. As virtualized applications proliferate, manual processes will struggle to meet the scale and speed of on demand virtual machine (VM) deployment.

SDN automation, using a centralized control plane with path computation based on real time network performance and APIs for programmable network configuration, can link to service delivery applications for on demand services. Regular automated network optimization can be scheduled to ensure optimal routing across the backhaul networks.

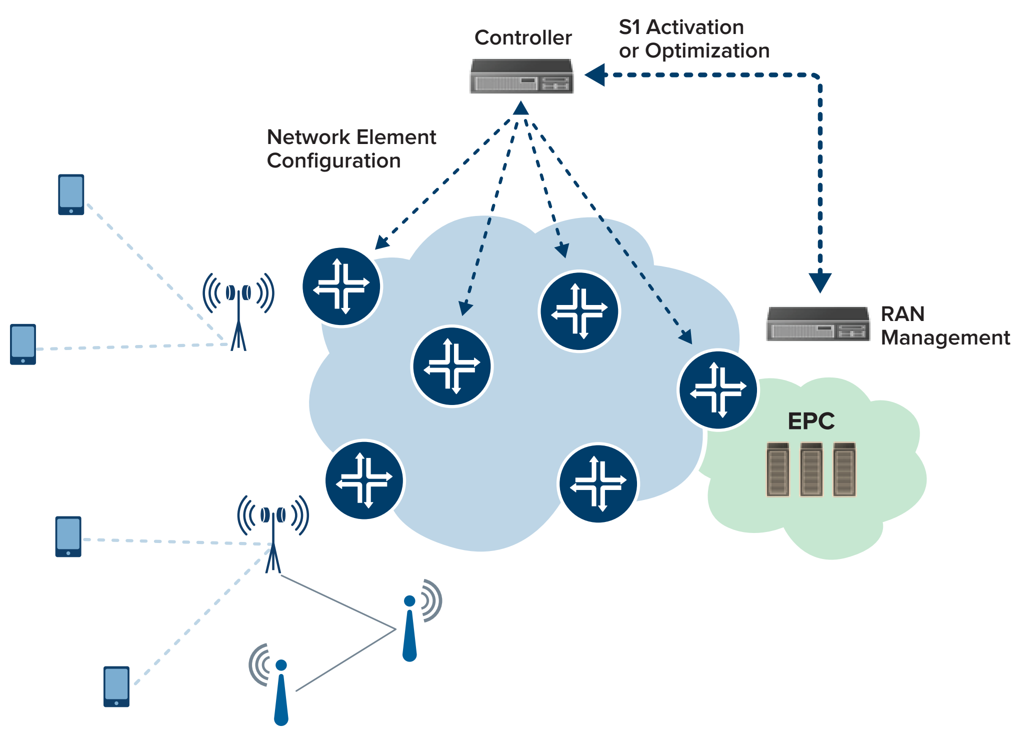

FIGURE 5 – SDN Automation of S1 Interface Activation and Optimization

Improved Network Utilization – Excess capacity is commonly provisioned in MBH networks for protection links in case of network outages. Under normal operation, these are underutilized network resources. Steady state network traffic usage is often capped at 60-70% of total link capacity to accommodate bursty traffic patterns and maintain user Quality of Experience (QoE). This combination of design criteria leads to networks operating at only 30-40% of potential capacity. Under a more dynamic control policy, if traffic bursts can be rerouted in real time to alternate paths based on congestion, and if protection paths can be used during normal times for unpredicted demand, network operators can better utilize link capacity. In addition, today's mobile networks were designed to direct all traffic to a central core, but as traffic patterns change and pass between cell sites, and as virtualized services replace static gateways, more efficient traffic distribution to local handoff points can reduce network load to the mobile packet core. Coriant analysis has estimated that these efficiency improvements can generate total MBH CapEx savings of up to 35%.

Deploying an SDN controller that incorporates network performance metrics and analytics into route optimization decisions is an important step toward achieving these efficiency goals. Advanced load balancing enabled by a centralized Path Computation Element (PCE) can also contribute to more flexible utilization of primary and protection paths.

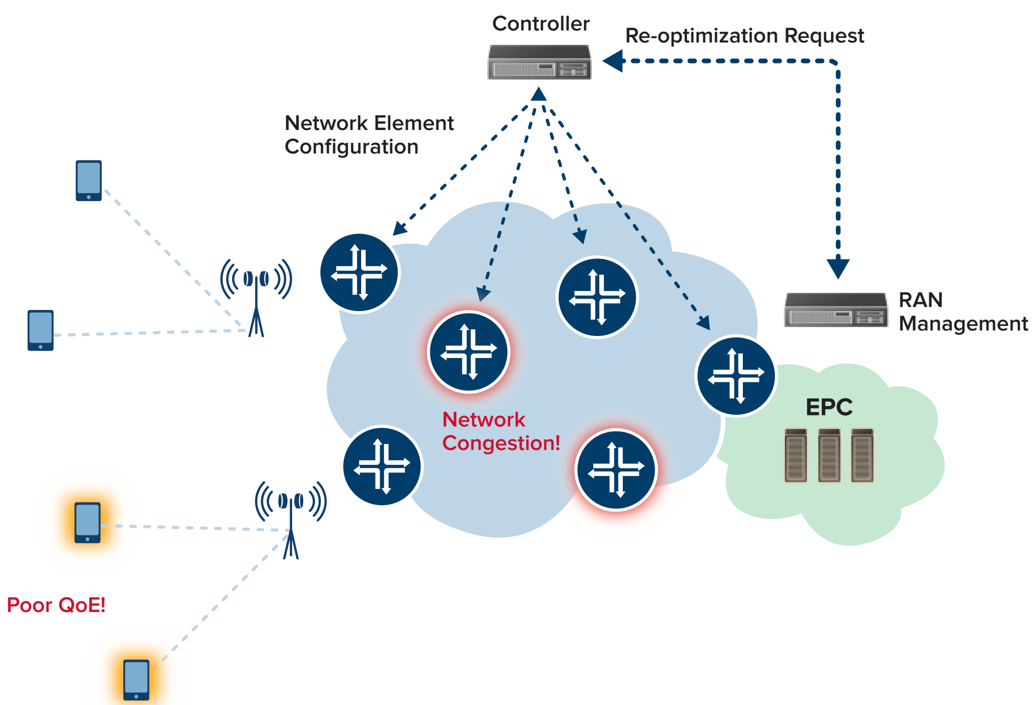

FIGURE 6 – Improved MBH Network Utilization under SDN Control

High Reliability, High Performance Services – Mobile networks today are generally designed to deliver best-effort data transmission for mobile devices with a limited number of traffic profiles for video streaming and social media apps. As cloud hosting of critical business services continues to grow, and as IoT applications demand new levels of performance, networks that support differentiated low latency/high availability services will generate new revenue streams and become a competitive advantage for service providers. Latency-sensitive applications under consideration include sensor networks, health monitoring applications, connected vehicle services, and first responder communications.

Centralized SDN controllers enable highly tuned service options by performing path computation using real time network performance data retrieved from the network through southbound APIs. Standardized northbound APIs allow a centralized SDN controller to tightly coordinate with RAN management and optimize overall network performance to suit the service type.

SDN also enables the RAN and backhaul network to correlate end user performance with current network status to optimize routing, QoS, and bandwidth allocation for better network performance. An external SDN control plane can load balance user traffic based on actual network congestion to better utilize expensive backhaul links and temporarily make use of protection circuits to absorb traffic bursts for improved user QoE. This type of coordination becomes even more valuable in converged networks that must accommodate the demands of both fixed and mobile users.

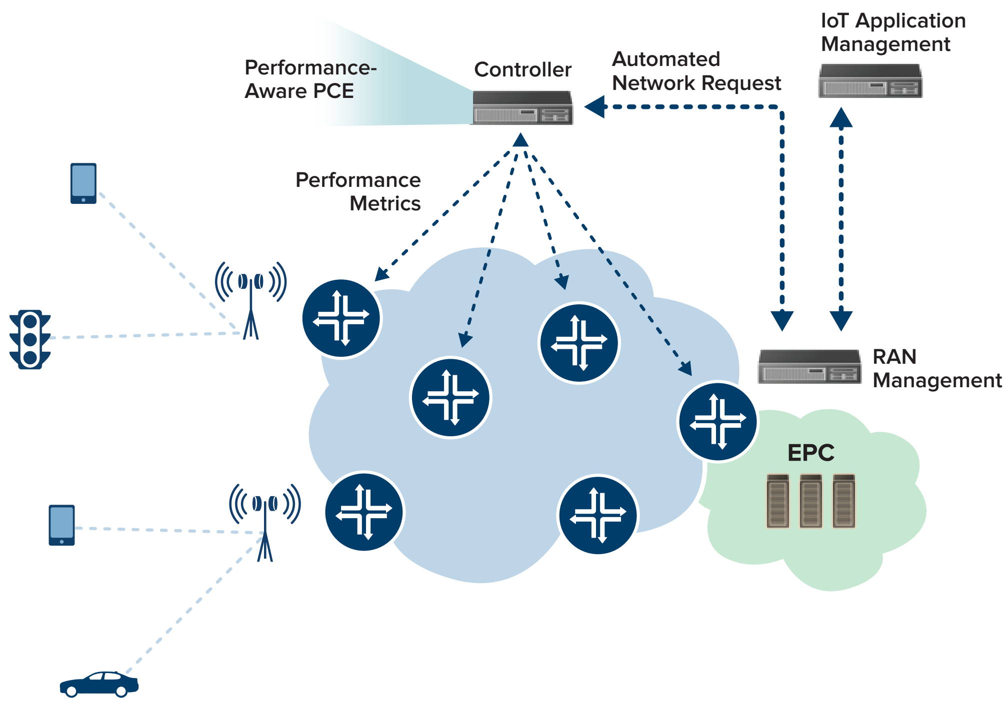

FIGURE 7 – Application-Aware MBH Network for High Reliability, High Performance Services

Network Support for Distributed Virtual Gateways – Mobile networks were designed to direct traffic through a hierarchy of controllers and gateways to a central Public Data Network (PDN) handoff point. In the dynamic network of the future, instead of routing to one central gateway, a mix of virtual resources (EPCs, ADCs, security gateways, etc.) will be available on demand, just as virtual servers are activated in data centers today. Virtual appliances will be distributed to more effectively cover urban metro areas, rural communities, enterprise customers, or dedicated IoT applications.

To support this dynamic environment, access and aggregation networks must adapt in real time to virtualized resources and provide network connectivity on the fly as virtual appliances are activated. SDN-based network automation is required where destination routing using static MPLS tunnels does not provide sufficient flexibility. Using SDN API calls based on a simplified network abstraction, applications will request the re-homing of end user traffic toward these newly activated resources or divert traffic to available capacity for disaster recovery or load balancing.

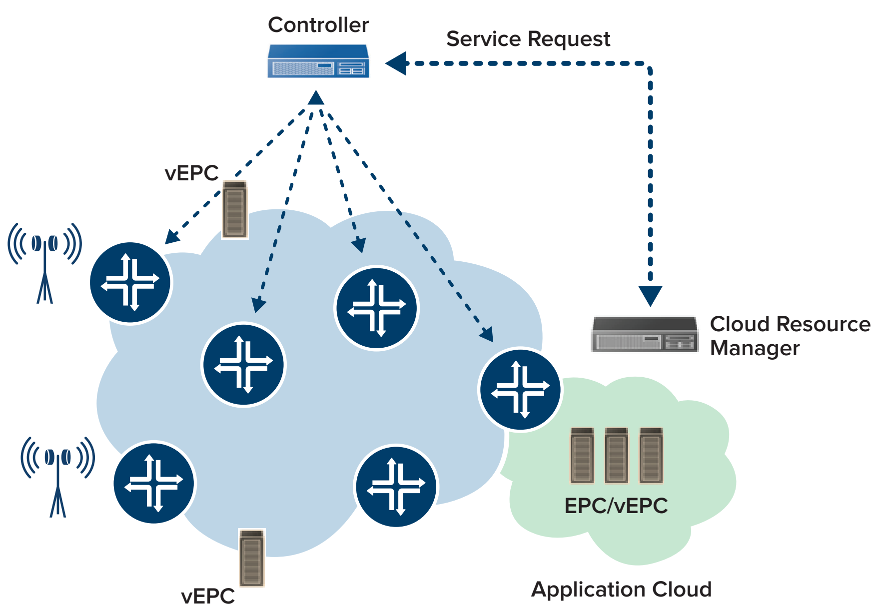

FIGURE 8 – SDN Control in an Access and Aggregation Network for Real Time Access to Virtualized Resources

Self-Organizing, Multi-Layer Networking – MBH networks are susceptible to bursty data traffic patterns. This will become more common with higher throughput speeds, more diverse end user terminals, heterogeneous network access points, and bandwidth hungry applications, such as virtual reality viewers and 3D video. Today, traffic bursts are managed by expensive over-provisioned networks or packet policers and shapers that drop or delay traffic and impact user QoE.

A programmable SDN control plane will enable service providers to alter forwarding rules in real time to divert traffic bursts to local gateway locations, neighboring cell sites, underutilized network paths, or cloud server farms. Forwarding rules can be based on current network performance and alternate path availability, replacing today's reliance on predefined static tunnels.

One substantial opportunity for improving resource utilization and reliability in MBH networks is through better multi-layer integration. Delivering the highest reliability mobile services requires diverse routing over redundant fiber or microwave transport paths, but in current MBH networks, the IP/MPLS layer has no direct visibility into the underlying transport network conditions. Multi-layer SDN provides the feedback path between optical and IP layers to enable optimized IP routing based on current optical network status. Similarly, as microwave radio transport capacity to cell sites is impacted by changing modulation rates, this status can be factored into router QoS thresholds and configured through the SDN control plane.

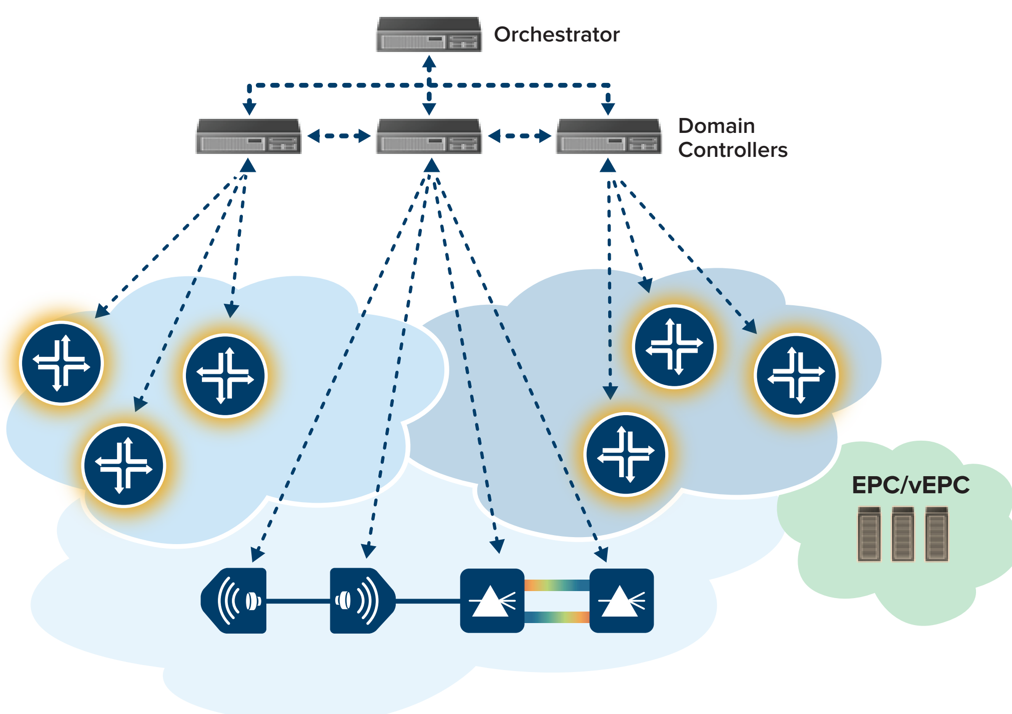

FIGURE 9 – Multi-Domain, Multi-Layer SDN Control for Improved Network Utilization and Reliability

SDN DESIGN PRINCIPLES

SDN in MBH promises new network efficiencies and compelling new services, but access networks, such as MBH networks, place unique demands on potential SDN solutions. Network planners responsible for MBH networks need a new set of practices to guide design and implementation decisions for SDN. Six recommended evaluation criteria offer a starting point when comparing potential SDN solutions for MBH.

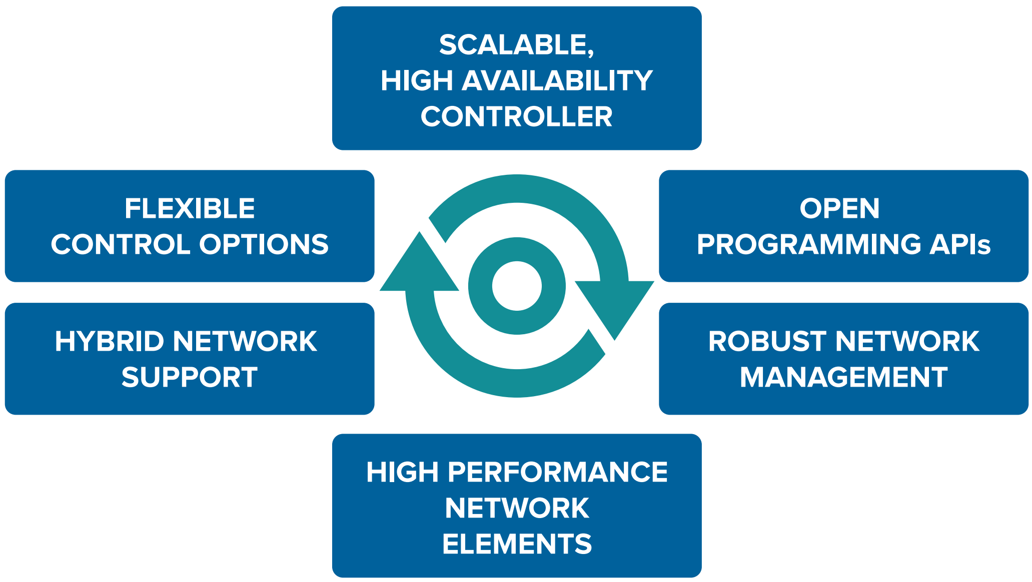

FIGURE 10 – SDN Solution Design Principles for Mobile Backhaul Networks

1. **Scalable, High Availability Controller** – The SDN controller is a critical new platform that enables programmatic control. It must be based on a fully redundant and secure platform so that a potential outage does not impact network performance. All communications to NEs must be encrypted, since network control updates will pass across these channels. The controller must be scalable to support both small metro area networks as well as national networks with tens of thousands of nodes. In many cases, a large scale, multi-vendor network will require a hierarchical controller architecture that integrates multiple controllers into a unified system.

2. **Flexible Control Options** – The most important control function of an SDN controller is a centralized PCE that can calculate traffic routing using traditional routing algorithms, while also incorporating real time performance criteria for optimized path computation. The controller must support a variety of network configuration interfaces to configure a broad array of services on a diverse set of new and existing NEs. It must be able to perform node discovery, learn current network paths and service configurations, and retrieve performance data for use in path computation as well as performance management and analysis.

3. **Open Programming APIs** – The creation of a programmable network is a key objective of SDN. Carrier applications and SDN orchestration platforms can make automated service requests to the SDN controller that are then mapped to network configurations. In some cases, the carrier may extract stateful network topology and specify explicit service routing as calculated in an external PCE. The controller can be a conduit for network performance information used for network analysis, SLA reporting, or as a basis for path computation. In addition, APIs can act as a communication path between multiple controllers for multi-vendor and multi-layer service orchestration. A full-featured set of APIs will allow service configuration with flexible service options (QoS, OAM service monitoring, synchronization, etc.) as well as the ability to request detailed performance updates.

4. **Hybrid Network Support** – The forklift replacement of existing hardware is both expensive and inefficient. While frequent swap-out of servers may be common in data centers, carrier access and aggregation networks are widely distributed across service regions and require visits to each node for any hands-on equipment upgrade or replacement. An SDN solution that interfaces with currently deployed NEs and can operate with existing NMS deployments in a hybrid mode provides a clean migration path to progressively validate and roll out network-wide SDN programmability and efficiencies.

5. **Robust Network Management** – While there are justifiably high expectations for the control plane enhancements promised by SDN, traditional network management functions are still essential. Alarms must be monitored and troubleshooting tools are needed to analyze issues on SDN-enabled nodes, although they may now be tied to the dynamic recovery options provided by SDN control. Even in a programmable network, performance must be monitored and managed. NMS-based configuration tools will continue to be valued by network operations staff and will benefit from SDN-based network programmability. At the same time, legacy services must continue to be managed, so an integrated system that seamlessly manages both legacy and SDN-enabled services is preferred.

6. **High Performance Network Elements** – While SDN is enabled by the addition of new control and orchestration elements, a robust network ultimately depends on high performance NEs. In controlled data center environments, these NEs may be software-based virtual routers, but in carrier access and aggregation networks, purpose-built high performance NE hardware will maintain the form factor and environmental specifications appropriate for operating within far-flung networks. In addition to forwarding traffic, these routers are required to provide performance monitoring, fault detection alarm generation, outage detection, and failover. They must support sophisticated traffic management functions and track network layer performance that is then reported to the central control platforms. Most critical for mobile networks is the delivery of network synchronization to ever-tightening standards.

CONCLUSION

Mobile backhaul networks are on the cusp of a major redesign to support next-generation wireless services. SDN promises to make this transition possible while also improving utilization and user QoE. With significant capital investment and operational complexity in existing MBH networks, network planners must carefully evaluate different approaches to SDN, as they undertake proofs of concept and live trials over the next 2-3 years. To gain maximum benefits from these initial deployments of SDN in MBH, network planners should have a clear understanding of the best potential applications and develop consistent criteria for solution evaluation.

ABOUT CORIANT

Coriant delivers innovative, dynamic networking solutions for a fast-changing and cloud-centric business world. The Coriant portfolio of SDN-enabled, edge-to-core transport solutions enables network operators to reduce operational complexity, improve utilization of multi-layer network resources, and create new revenue opportunities. Coriant serves leading network operators around the world, including mobile and fixed line service providers, cloud and data center operators, content providers, cable MSOs, large enterprises, government agencies, financial institutions, and utility companies. With a distinguished heritage of technology innovation and service excellence, forged by over 35 years of experience and expertise in Tier 1 carrier networks, Coriant is helping its global customers maximize the value of their network infrastructure as demand for bandwidth explodes and the communications needs of businesses and consumers continue to evolve. Learn more at www.coriant.com.