



Applications and use cases of Software Defined Networking (SDN) as related to microwave and millimetre wave transmission

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) millimetre Wave Transmission (mWT).

Modal verbs terminology

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Executive summary

The present document presents and analyses some use cases for Software Defined Networking (SDN) focusing on the application of microwave (MW) and millimetre wave (mmW) transmission.

In particular millimetre wave technologies are considered a basic enabler for the future of telecommunication networks, for both access (5G mobile) and fronthaul/backhaul.

Fundamental aspects of those future networks are performance, flexibility and adaptivity far beyond what is possible today, with technologies like SDN and Network Functions Virtualization (NFV) providing the prerequisite capabilities.

The need for future mmW radio to coordinate with other transport and access technologies requires that the mmW ecosystem at least understand the scenarios and use cases in which the equipment will be integrated.

The goal of the present document is to provide an overview of applications and use cases that, leveraging on the SDN paradigm, are able to add value in terms of functionality, efficiency and/or cost when using microwave/millimetre wave network segments.

The peculiar characteristics of MW and mmW radio networks are to be taken into account in order to define the specific use cases and value propositions, which are both pertinent and compelling.

In perspective, an SDN network where a centralized intelligence can make the most of the huge amount of data coming from the current and past status of the entire network and its applications, will allow for innovative, dynamic and highly efficient services and operation, to levels not seen before.

Not secondary in this perspective is the promise of SDN to cross over equipment technology, network segment and vendor boundaries.

It is not in the scope of the present document to enter in any way into discussions about controller architectures, protocols, information models and implementation details since other specific Standard Defining Organizations (SDOs) are already in charge of these important issues.

In fact the present document is to be seen as complementary to the work done in other SDOs.

Introduction

The current architecture of telecom and data networks is based on the IP protocol stack, where the routing philosophy is made of *distributed control* and *hop by hop* decisions over single *data packets*.

This approach is beginning to show some limits in terms of performance, flexibility and scalability due to the exponential growth of data traffic that has been experienced for some years, in particular with the explosion of the quantity and quality of applications and terminals that require to be connected.

The requirements on the different traffic types range from high throughput to low latency, from high user density to high availability, from low power consumption to high reliability. The fulfilment of such a wide variety of requirements asks for a quite different network architecture, where adaptivity is fundamental.

In order to answer to this necessity several approaches have been proposed in the recent years, having in common the focus on the programmability offered by software:

- Cloud networking
- Network Functions Virtualization (NFV)
- Software Defined Networking (SDN)

In particular Software Defined Networking is an approach to networking based on the following principles:

- The separation of the data plane from the control plane
- The logical centralization of the control function

The routing philosophy introduced by SDN is based on *centralized control* able to perform *end-to-end* decisions over *data flows*.

The main concept is to have network elements with just forwarding functions, with on top a central controller which is able, on one side, to expose an abstracted view of the network resources to the applications and, on the other side, to allow an automated implementation of services independent from the physical details of the network.

As such this architecture is structured on three basic layers:

- Data plane, made of the different network elements (NEs)
- Control plane, which is the central controller
- Application plane, made of the different applications

The interface between control plane and data plane (SouthBound Interface, SBI) has the goal to allow for standard protocols to be implemented, two examples being OpenFlow and Netconf; in this way the goal would be to have a controller which is able to interact with NEs independently from the vendor specificity.

The interface between the application plane and control plane (NorthBound Interface, NBI) has the goal to allow Application Programming Interfaces (APIs) to be established so that applications can be developed independently from the particular physical network.

The specific SDN architecture is the object of several SDOs and is out of the scope of the present document. The focus of this work is to analyse and define use cases and applications in the domain of microwave (MW) and millimetre wave (mmW) transmission in which the SDN paradigm can be effectively applied.

1 Scope

The purpose of the present document is to provide information on the applications and use cases of the SDN paradigm as related to MW and mmW transmission.

The analysis covers the following *progressively widening ranges*:

- 1) The radio link network segment in itself.
- 2) The interactions of the radio link network segment with an adjacent segment.
- 3) The radio link network segment as a part of an end-to-end connection.

Even if going towards a wider network range the relevance of the MW/mmW segment may become less evident, nevertheless the relevance of SDN is at its highest level when considering end-to-end scope, where the MW/mmW segment is just a part of the whole picture but anyway requested to be able to adapt to the SDN requirements in order for services to be efficiently and effectively provisioned.

The classification of applications and use cases in the three aforementioned broad categories reflects a natural layering in terms of scope width, increasing complexity and increasing value, in terms of cost reduction, enabler for new revenue streams and enabler of innovations not yet thought of.

It has to be noted that several use cases described in a given network range (and clause) become part of the use cases described in the wider network range (and following clause) in a sort of recursive and *auto-similar* behaviour; it is anyway useful to keep the use case in all the relevant clauses in order to highlight the significant increase in value and decrease in cost that is achieved by extending the use case from segment towards end-to-end scope.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Open Networking Foundation: "Wireless Transport SDN Proof of Concept White Paper".

NOTE: Available at https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/ONF_Microwave_SDN_PoC_White_Paper%20v1.0.pdf.

[i.2] Open Networking Foundation: "Wireless Transport SDN Proof of Concept 2 Detailed Report".

NOTE: Available at https://www.opennetworking.org/images/stories/downloads/sdn-resources/technical-reports/Wireless_Transport_SDN_PoC_White_Paper.pdf.

[i.3] Open Networking Foundation: "Third Wireless Transport SDN Proof of Concept White Paper".

NOTE: Available at <https://www.opennetworking.org/images/stories/downloads/sdn-resources/technical-reports/Third-Wireless-Transport-SDN-Proof-of-Concept-White-Paper.pdf>.

[i.4] NGMN Alliance: "NGMN 5G white paper".

NOTE: Available at http://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0_01.pdf.

[i.5] SDN World Congress 2016: "Enabling 5G network slicing with programmable microwave transport".

NOTE: Available at <http://www.layer123.com/sdn-webcast-mle123>.

[i.6] IEEE™: "SDN-based architecture to support Synchronization in a 5G framework".

NOTE: Available at <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7579504>.

[i.7] "Securing the Cloud with SDN".

NOTE: Available at <https://www.sdxcentral.com/articles/analysis/securing-cloud-sdn/2016/05/>.

[i.8] Recommendation ITU-T G.8275.1: "Precision time protocol telecom profile for phase/time synchronization with full timing support from the network".

[i.9] Recommendation ITU-T G.8261: "Timing and synchronization aspects in packet networks".

[i.10] Recommendation ITU-T G.8262: "Timing characteristics of a synchronous Ethernet equipment slave clock".

[i.11] Recommendation ITU-T G.8264: "Distribution of timing information through packet networks".

[i.12] Recommendation ITU-T G.8272: "Timing characteristics of primary reference time clocks".

[i.13] Recommendation ITU-T G.8272.1: "Timing characteristics of enhanced primary reference time clocks".

[i.14] Recommendation ITU-T G.8273.2: "Timing characteristics of telecom boundary clocks and telecom time slave clocks".

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

5G	Fifth Generation of Mobile Networks
API	Application Programming Interface
ATPC	Automatic Transmit Power Control
BC	Boundary Clock
BCA	Bands and Carrier Aggregation
BMCA	Best Master Clock Algorithm
BSS	Business Support System (customer facing activities)
BTS	Base Transceiver Station
CAPEX	Capital Expenditures
CIR	Committed Information Rate
CO	Central Office
CoMP	Coordinated MultiPoint
CPE	Customer Premises Equipment
DCN	Data Communication Network (management network for telecommunication systems)
DoS	Denial of Service
E2E	End-to-end
eMBMS	evolved Multimedia Broadcast Multicast Service
FTP	File Transfer Protocol
FWA	Fixed Wireless Access
GM	Grand Master
GPS	Global Positioning Service
IoT	Internet of Things
IP	Internet protocol
KPI	Key Performance Indicator

LOS	Line Of Sight
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
M2M	Machine to Machine
mmW	Millimetre wave
MPLS	Multi Protocol Label Switching
MPtMP	MultiPoint to MultiPoint
MTBF	Mean Time Between Failures
MW	Microwave
n/NLOS	near/Non Line Of Sight
NaaS	Network as a Service
NBI	NorthBound Interface
NE	Network Element
NFV	Network Functions Virtualization
NMS	Network Management System
OAM	Operation Administration and Maintenance
ONF	Open Networking Foundation
OPEX	Operational Expenditures
OSS	Operational Support System (network facing activities)
PIR	Peak Information Rate
PMP	Point to MultiPoint
PoC	Proof of Concept
PoP	Point of Presence
PTP	Precision Time Protocol
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
SBI	SouthBound Interface
SDN	Software Defined Networking
SDO	Standard Defining Organization
SLA	Service-Level Agreement
SON	Self Organizing Network
SW	SoftWare
TDD	Time Division Duplex
TTM	Time To Market
UL/DL	Uplink/Downlink
VLAN	Virtual LAN
VPN	Virtual Private Network
WttC	Wireless to the Cabinet
WttH	Wireless to the Home

4 Applications and use cases: overview

4.1 Differentiators of MW/mmW technology

The main peculiarities of the wireless transport networks which differentiate them from other transport technologies (for example optical and/or packet) are:

- 1) Dynamic nature of the communication channel, due for instance to interference, rain attenuation, multipath fading.
- 2) Huge number of nodes per area to be controlled (scalability). This places an issue on the stability of the controlled network, since control information has to reach each node avoiding oscillations, information storms and inconsistencies.
- 3) Limited time scale of control channel (DCN bandwidth), due to current use mainly for configuration and monitoring.
- 4) Street-level peculiarities, for instance multipath, pole oscillations, temporary obstructions, power availability.

- 5) Low number of functions to be virtualized.
- 6) Mostly non-redundant paths (tree/chain topologies, usually no rings/meshes), even if innovative traffic management systems implemented thanks to SDN may make rings/meshes attractive in the wireless backhaul.
- 7) Spectrum use regulation limits what can be automated in RF planning, automated antenna pointing, etc.
- 8) Transmission bandwidth impacts power consumption in a very limited way (unless turning on/off a complete carrier).

4.2 Considerations on time scale

The actions of an SDN controller can be fundamentally grouped into 2 categories:

- 1) Actions triggered by events happened in the network
- 2) Actions not directly dependent on a specific network event

In the first case, the main parameters to be considered are:

- Event speed
- Event duration
- Event frequency

The reaction time of the SDN system is dependent on different factors:

- Time for notification to be received by the controller
- Elaboration time in the controller
- Time for command to be received by the network elements

The geographical scope and the bandwidth of the control channel can set in some cases the lower limit to the reaction time of the controller, depending on the location of the controller and on the technology used for the control channel.

The second type of SDN action is asynchronous from any network event and comprises for example:

- Network (re)configuration
- Provisioning of new services
- Continuous network optimization

In general at least four different time scales can be identified:

- 1) Events requiring very fast (typically hardware) action on the single NE (e.g. protection switching).
- 2) Events requiring quite fast (typically software) action on the single link (e.g. adaptive modulation and coding, ATPC).
- 3) Events requiring relatively slow (typically software) action (e.g. load balancing due to instantaneous traffic load and link status).
- 4) Events requiring very slow (typically software) action (e.g. slow interference events, long-time-scale traffic patterns).

The capacity of the control plane, the DCN resources and the required time scale of consequent reaction are expected to restrict the application scope of SDN to events of the last two types, i.e. with a sufficiently long time scale for notification, elaboration and reaction. As a general reference a discriminating time scale for SDN to be able to effectively operate is on the order of seconds, whilst sub-second variations are out of SDN scope.

Moreover it has to be highlighted that whenever the NE is able to perform a proper reaction locally on its own there is no reason for a centralized control system to be involved.

Time scale	Functional examples	SDN applicability
Very fast	Protection switching	No
Quite fast (sub-second)	Adaptive modulation, traditional ATPC	No
Relatively slow (seconds)	Dynamic adaptation to link and/or traffic variations	Yes
Very slow/static	Slow events, configuration, OAM, QoS	Yes

5 Applications and use cases: description

5.1 Radio link network segment in itself

5.1.1 Introduction

The use cases of this clause are characterized by the fact that all information and action are contained within the MW/mmW radio network domain.

There is no coordination with other technologies or other network layers (e.g. the RAN), even if the information about the status and the events in the mmW radio layer can be made available and used by any other entity in the SDN ecosystem.

5.1.2 Efficient power consumption

Energy saving is one major goal of both current and future networks.

In addition to specific power-saving mechanisms that can be built in the equipment hardware, more sophisticated mechanisms and their activation can be devised and controlled by a centralized application, based on deep data analysis from historical and current network configurations and load conditions.

Such mechanisms can include activation/deactivation of carriers in multi-carrier systems, advanced low-power states and even intelligent power down of parts of the network (with reconfiguration of the remaining radio network).

As an example consider a high power long haul link made of 4 carriers. Each carrier consumes around 40 to 50 Watts; overall the 4 carriers consume about 200 Watts. In the case that during night time capacity drops to $\frac{1}{4}$ of the peak, 150 Watts can be saved. With a traffic profile that looks like:

Time of Day	Amount of traffic versus peak
5:00 to 8:00	50 %
8:00 to 10:00	75 %
10:00 to 16:00	100 %
16:00 to 20:00	75 %
20:00 to 24:00	50 %
24:00 to 5:00	25 %
Daily Average	63,54 %

In this case power savings in the order of 36 % can be achieved.

Carrier activation/deactivation in multi-carrier systems triggered by the traffic level has been demonstrated in ONF PoC of October 2015 under the name "capacity driven air interface" [i.1].

Value	• Save OPEX without impacting service • Meet energy efficiency targets • Optimize equipment cost • Easy target to start working on smart network power consumption management
Specific needs to be addressed	• Reduce power consumption • Reduce equipment wear
Applicability	• Multi-directional hub, multi-carrier/multi-channel radio links
Time scale of events	• A few hourly events
Reaction time of SDN	• Tenths of seconds
Specific contribution to/from SDN	• Centralize control of this function, using network-wide data (also across other domains) to perform data analysis, prediction and optimize the power-off time • Easy integration with other transport technologies
Potential issues/problems	• Repeated power cycling effect on MTBF • Reliability of the restart process • Data analysis & prediction algorithm efficiency
Related/dependencies	• More comprehensive energy saving schemes at network level (see clause 5.2.6) • ONF PoC capacity driven air interface, October 2015 [i.1]

5.1.3 Dynamic traffic distribution

Ring and mesh topologies have not been used very much in the past for MW and mmW networks, mostly due to the centralized architecture of 2G and 3G networks, where no communication among peripheral sites was required. Therefore, using ring or mesh topology was only done for geographical network protection, restricting their economic attractiveness. Due to the flexibility introduced by packet transmission and to the new and increasing connectivity requirements among peripheral nodes (e.g. LTE X2), ring and mesh topologies are expected to enjoy a new popularity.

Thanks to the automation and the optimization made possible by an SDN system using big data analytics about the network conditions, mesh architectures could provide the throughput, adaptability and resiliency that are increasingly demanded from the networks. A significant example is providing small cell backhaul in a dense urban scenario at street level.

When more than one path exists across the network, traffic can be dynamically distributed over the available links in order to:

- 1) Maximize throughput based on link topology and actual capacity as triggered by a variation in traffic.
- 2) Provide resiliency by reacting to capacity changes (e.g. adaptive modulation), load changes, link interruptions (e.g. LOS transient blockage at street level), transient interference problems or link failures.
- 3) Provide synchronization redundancy.

Due to certain mobile access features requirements (e.g. inter-site carrier aggregation, CoMP, etc.), phase/time synchronization is required. One of the many available options is backhaul networks (including also radio links) to support the relevant ITU-T Packet Synchronization Recommendations, such as Recommendation ITU-T G.8275.1 [i.8]. A key to the resiliency of the Precise Time Protocol (PTP) is the Best Master Clock Algorithm (BMCA), which specifies the way by which each clock determines the best master clock in its sub-domain out of all clocks it can see, including itself. In case of synchronization failure (e.g. due to a faulty unit), an SDN controller could make the necessary computations and decide on-the-fly, which should be the new master clock for a given PTP-aware node (assuming a topology that allows such an action).

- 4) Provide flow handling (e.g. video distribution/multicast).

Backhaul networks (including also radio links) benefit from multicast connections that are established for specific type of services, since available bandwidth is consumed in a more efficient manner. Evolved Multimedia Broadcast Multicast Service (eMBMS) is only an indicative example, in which data is transmitted from a single source entity to multiple recipients. The nature of such services is not constant, but they should be available when a group of users (authorized subscribers) initiate the relevant requests to the network. An SDN controller could decide and apply on-the-fly a multicast connection (service provisioning), when there is such a need and where (namely, on which radio links) it is needed.