DOCSIS® FOR LTE SMALL CELL BACKHAUL

ADDRESSING PERFORMANCE AND THROUGHPUT REQUIREMENTS FOR MOBILE BACKHAUL

WHITE PAPER

Small cells can be used to increase wireless network capacity, provide coverage in areas where there is no or poor macro cell coverage, or to provide contiguous coverage and capacity in targeted high-value locations. Control signaling performance (delay/jitter/loss) and bandwidth throughput needs for small cells can place very stringent requirements on backhaul networks. The use of cable networks, given the extensive distribution of coax across residential and business locations, is one option for small cell backhaul. Therefore, it is important to understand the small cell performance and throughput levels that different cable networks can support, given their varying characteristics.

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INTRODUCTION

Hybrid-Fiber Coax (HFC)/Data over Cable System Interface Specification (DOCSIS®) access networks are widely used to address the needs of residential and enterprise consumers for High Speed Internet (HSI), video, and voice services. A hot question these days is:"Can HFC/DOCSIS access networks also support the backhaul needs of Long Term Evolution (LTE) small cells." The primary concern is about meeting throughput and performance (packet delay/jitter/loss) requirements, and many factors play a significant role in determining the feasibility of any given network. As the characteristics of cable networks can vary significantly across markets, it is not always possible to have a clear yes/no answer.

The objective of this paper is to identify key factors that influence the viability of HFC/DOCSIS access networks for LTE small cell backhaul, along with key performance requirements.

BACKHAUL CONSIDERATIONS FOR SMALL CELLS

Use Cases

Small cells have three fundamental use cases:

1. Increase wireless network capacity in traffic 'hotspots', typically characterized by islands of small geographical areas (often 100's of square meters).
2. Provide coverage in areas where there is no, or poor, macro cell coverage (e.g., indoor areas and/or at macro cell edges), sometimes called "nought spots".
3. In a recently emerging trend, provide contiguous coverage and capacity in targeted high-value areas (e.g. business districts, commercial zones, etc.), also known as "hot zones" or "performance zones" in major cities.

The primary motivation for small cell deployment is delivering higher user experience with better economics. Sometimes small cells may also be deployed because of practical deployment constraints, e.g., non-availability of macro sites, radiation concerns, etc. Small cells are generally used in conjunction with macro cells in a HetNet (Heterogeneous Network) architecture where the macro network provides voice services and high mobility data services (e.g., in-car usage), while the small cell provides data services for low mobility/nomadic users (which accounts for 70%+ of today's data consumption in most networks). Small cells are best suited for serving applications with high Quality of Service (QoS) requirements (e.g., video streaming, video calling, etc.) which need high throughput and low delay/jitter/packet loss.

Environmental

Small cells are typically used in two types of environments:

1. Indoor – for residential, enterprise, or within commercial buildings, malls, stadiums. In this environment, small cells are often mounted on ceilings or walls.

2. Outdoor – for business or commercial districts, entrance to train stations, bus stops, popular squares etc. In this environment, small cells are mounted on facilities such as utility poles, building facades, lamp posts, etc.

Small cells, unlike macro cells, are often deployed in clusters based on capacity or coverage needs. Consequently, the type of environment has a major correlation with the anticipated user demand, and hence, the potential bandwidth requirement for traffic backhaul.

Throughput

Backhaul bandwidth requirements for small cells are primarily driven by two criteria:

1. Amount of spectrum used by the small cell (typically 5, 10 or 20 Mega Hertz - MHz).
2. Number of sites connected to a site in hub or daisy-chain topology.

Typically, a 20 MHz Frequency-Division Duplexing (FDD) small cell needs to be sized for 100 Mega bits per second (Mbps) Downlink/ 50 Mbps Uplink for backhaul purposes. A 5 or 10 MHz FDD cell will require proportionately smaller bandwidth allocation. The user experience within the coverage footprint of small cells depends on several things, including interference from the macro network as well as number of simultaneous users on the small cell.

Performance

Many performance requirements for voice, data and video do not present a fundamental challenge for an HFC/DOCSIS access network.

Packet delay, jitter and loss requirements for different classes of service (Conversational, Interactive, Streaming and Background) over an LTE radio link are documented in 3rd Generation Partnership Program (3GPP) TS 22.105. Additionally, recommendations for classifying common end-user services under different Quality Class Indicators (QCIs) for LTE are captured in 3GPP TS 23.203. For services such as Conversational class, failure to meet the delay requirements for bearer signaling can result in significant service degradation. Yet, none of these performance requirements is so stringent that they present a fundamental challenge for an HFC/DOCSIS access network.

On the other hand, control signaling performance requirements for LTE radio access networks are more stringent and may present a challenge. For example, during a handover preparation phase (one cell handing off to another), the source and target cells need to quickly exchange configuration information via X2 or S1 interfaces. The longer the handover preparations phase, the higher the chance of handover failure. Failure to meet the delay requirements for bearer signaling can result in significant service degradation. This is a primary area of concern for HFC/DOCSIS-based backhaul.

The delay requirement for transport between the small cell and the Evolved Packet Core (EPC) system is fairly stringent. It is recommended that the delay is kept around 5 milliseconds (ms) for optimal network performance.

HFC/DOCSIS PERFORMANCE

This section explores HFC/DOCSIS access network backhaul of LTE small cells. Figure 1 illustrates an outdoor deployment of small cells using an HFC/DOCSIS network for backhaul.

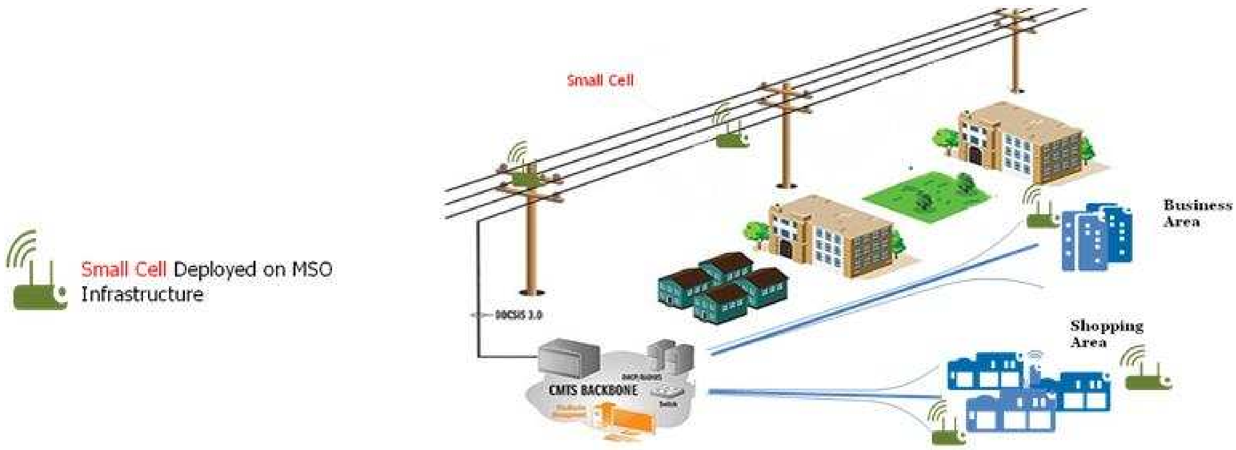

Figure 1: Small Cell Backhaul on an HFC Access Network

Throughput

It is given that the Uplink and Downlink bandwidth requirements of a small cell will vary. HFC/DOCSIS provides a channelized access network architecture, consisting of either 6 MHz or 8 MHz channels in the downstream direction (analogous to wireless Downlink), and typically 6.4 MHz channels in the upstream direction (analogous to wireless Uplink), although the width of the upstream channel may vary. Downstream and upstream channels are used to carry voice, data and video traffic. Today there are only a handful of upstream channels, while there are well over 100 downstream channels.

A downstream 6 MHz HFC channel using DOCSIS 3.0 (the current standard) for data services can typically achieve ~38 Mbps of throughput and an 8 MHz channel can achieve ~50 Mbps of throughput using 256 Quadrature Amplitude Modulation (QAM). A 6.4 MHz upstream channel may achieve ~28 Mbps using 64 QAM. To improve aggregate throughput, channels can be bonded together, for example in groups of 4, 8 or higher. A service group concept is used to define how DOCSIS channels are allocated to serve consumers over a defined geographic area.

For downstream traffic, service groups can either be dedicated to small cell backhaul, or shared with residential or enterprise traffic. The choice will depend on traffic volumes and available channels. Service groups may be shared by hundreds of consumers, each contending for precious bandwidth. Dimensioning the upstream on the HFC/DOCSIS access network to support small cell backhaul is more complex given the limited number of available upstream channels and lower throughput per channel. Depending on whether or not sufficient upstream or downstream channel capacity exists, DOCSIS service groups may need to be split to reduce the size of the geographic serving area, thus allowing a lower number of small cells, or small cells plus residential consumers and enterprises, to share available channel bandwidth. Service group splits require network changes and costly additional HFC/DOCSIS equipment.

In addition, small cell locations are engineered based on complex algorithms to provide capacity increase or areas coverage. New infrastructure may be needed to reach small cell locations if coax is not already present.

Performance

There are several important factors that contribute to performance issues in HFC/DOCSIS access networks, including:

- DOCSIS QoS – multiple QoS mechanisms are available to prioritize DOCSIS data flows. These mechanisms can be used to give preferential treatment to control traffic, such as those from small cells, thus theoretically reducing packet delays. The choice of the QoS mechanism can impact backhaul performance.
- Use of a single DOCSIS channel vs. bonded DOCSIS channels for backhaul – slight increases in delays may be incurred when channels are “bonded” to create higher throughput, due to packet processing delays associated with the time alignment of the multiple DOCSIS channels.
- Equipment used – design, implementation, and device components used can contribute to equipment performance differences between DOCSIS vendors.
- Consumer traffic – contention for bandwidth by residential and enterprise consumers, or by multiple small cells themselves. Peak busy hours of the day will have more contention for bandwidth.
- Fiber and coax lengths – while not a large contributor to delays, excessive lengths contribute to propagation delays in the HFC and Internet Protocol (IP) networks.

The largest delays may occur in the upstream direction due to the packet delays caused by the inherent nature of processing DOCSIS upstream channels (grants, maps and contention resolution mechanisms), QoS mechanism, and cable modem packet processing. Delays may impact quality of experience.

Figure 2 illustrates where delays may be incurred in an HFC/DOCSIS network.

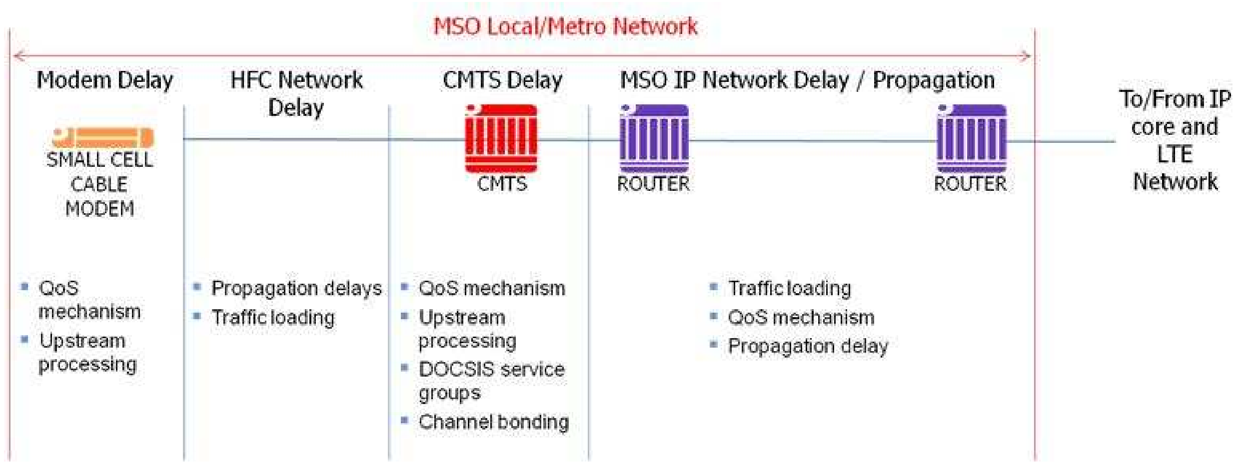

Figure 2: HFC/DOCSIS Delays

Powering

Current power systems for HFC networks tend to be engineered for ~80% of their power capacity. The addition of small cells that are powered directly from the coax network may place a strain on existing system power sources. External power sources may need to be considered.

CONCLUSION

The feasibility of using HFC/DOCSIS access networks for traffic backhaul from small cells depends on many factors including use case, traffic mix, environment, peak busy hour demand, HFC/DOCSIS network characteristics, performance objectives and QoS mechanisms. There are no commercial examples of large-scale usage of HFC/DOCSIS access networks to backhaul traffic from small cells or macro cells at this time. The feasibility and design/cost tradeoff of using HFC/DOCSIS networks for backhaul can be determined through a detailed techno-economic analysis.

ACRONYMS

CMTS	Cable Modem Termination System
DOCSIS	Data Over Cable System Interface Specification
EPC	Evolved Packet Core
FDD	Frequency-Division Duplexing
3GPP	3rd Generation Partnership Program
HetNet	Heterogeneous Network
HFC	Hybrid-Fiber Coax

HSI	High Speed Internet
IP	Internet Protocol
LTE	Long Term Evolution
Mbps	Mega bits per second
MHz	Mega Hertz
ms	milliseconds
MSO	Multiple Systems Operator
QAM	Quadrature Amplitude Modulation
QCI	Quality Class Indicators
QoS	Quality of Service
TS	Technical Specification

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