NSERC CRSNG

SUSTAINABLE BROADBAND PROVISIONING IN NEXT-GENERATION SMART UNIVERSITY CAMPUS

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INTRODUCTION

Today, broadband Internet is instrumental in social management, economic growth and global competitiveness, and even a better way of life, especially in urban environments. Universities and their knowledge networks of researchers, faculty, and students create hubs of innovation and productivity at the center of regional and urban developments, based on robust network connectivity to improve competitiveness in research and education as well as to facilitate collaboration.

A campus has to be designed with a high capacity and flexible network supporting various types of bandwidth consuming applications, like peer-to-peer file sharing and video interactive services. It is an open integrated environment with multi-layer wire and wireless infrastructures connected to various institutions and other points of presence (POP) in communities. In particular, one of key issue when deploying a broadband plane in university campus is optimization of resource and traffic in order to avoid excessive overprovisioning which results in damaging environmental impacts.

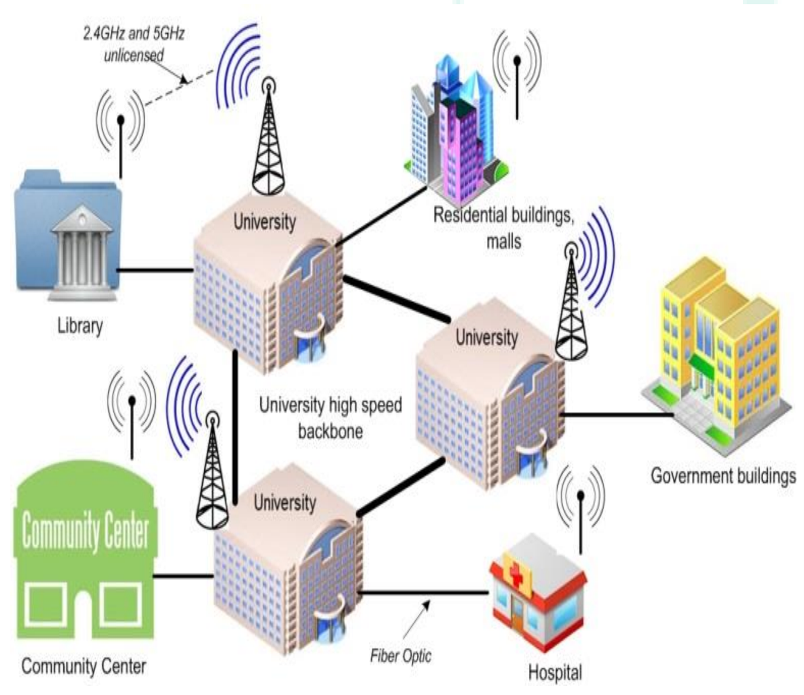


Fig.1. University as a hub for open access network model

OPEN ACCESS CAMPUS NETWORK MODEL

This model is based on **open access** to fiber build-out of university campus, especially with respect to wireless deployment. Wireless adds exponential use value to fiber installed to the premises of community centers.

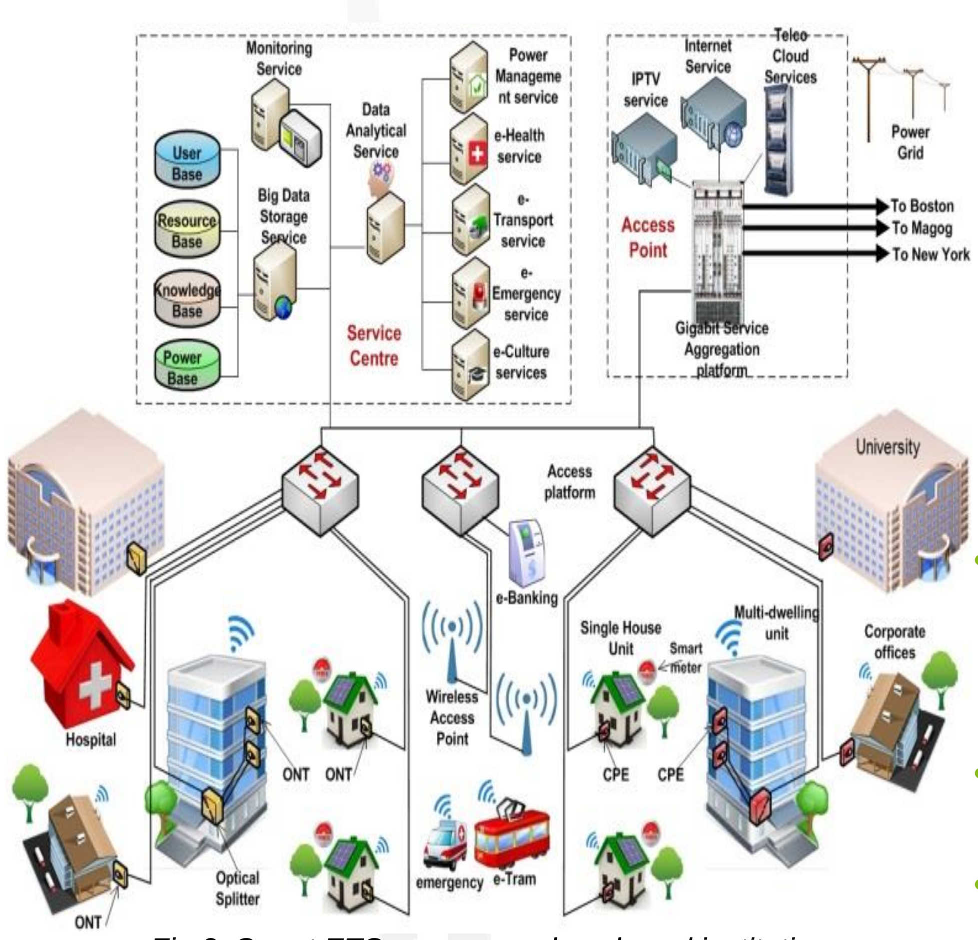
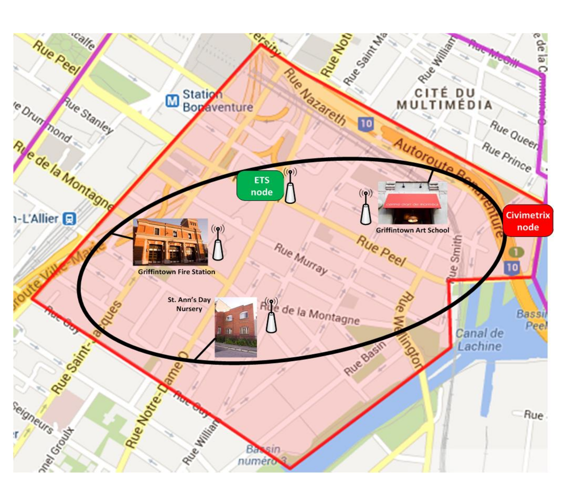


Fig.2. Smart ETS campus and anchored institutions



- A smart residential campus of Ecole de Technologie Superieure, University of Quebec, Canada.
- Located in downtown Montreal, 2.1 sq km.
- 100 apartments divided into experimental & control groups

- Optical rings encircle several neighborhoods with high-capacity fiber, connecting businesses, anchor institutions, and community residents.
- Ringed areas serve as foundations for wireless mesh networks, which in turn push connectivity outward into surrounding neighborhoods.
- Mesh wireless is a device-as-infrastructure architecture using common standards such as 802.11n Wi-Fi on 2.4 GHz and 5GHz WiFi.

Providing platforms and applications on ultra-broadband infrastructure:

- Software-defined networking: to program university campus network on-demand; a logical controller directly configures the underlying switches.
- Gigabit-class symmetrical speeds to the end user: to ensure quality of services (QoS) of network applications.
- Neighborhood clouds: to offload traffic and computing requirements to nearby infrastructure.

Cloud-based smart community

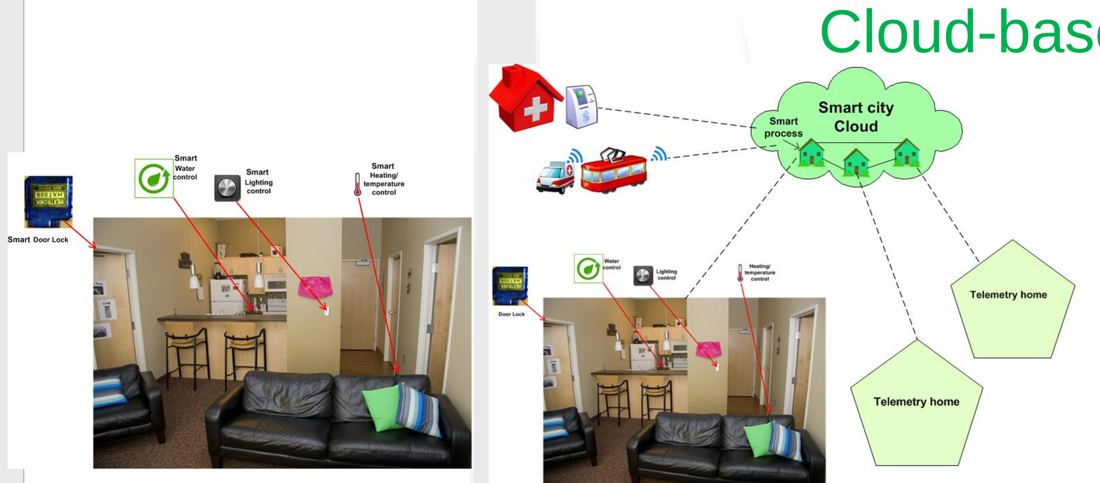


Fig.3. A smart home vs. a smart community

- Bring intelligence from individual household devices to cloud
- Environmentally optimize a community, not a single home
- … and cloud services are also green!

NETWORK ENERGY CONSUMPTION

FTTH consumption

In each apartment, an optical network termination (ONT) is connected by an individual fiber to an optical line termination (OLT) port at an optical switch.

- N: the number of apartments
- P_{ONT}, P_{Switch}: power consumption of ONT and switch
- N_{Switch}: the number of users sharing a switch

$$P_{FTTH} = N \times (P_{ONT} + 2 \times \frac{P_{Switch}}{N_{Switch}})$$

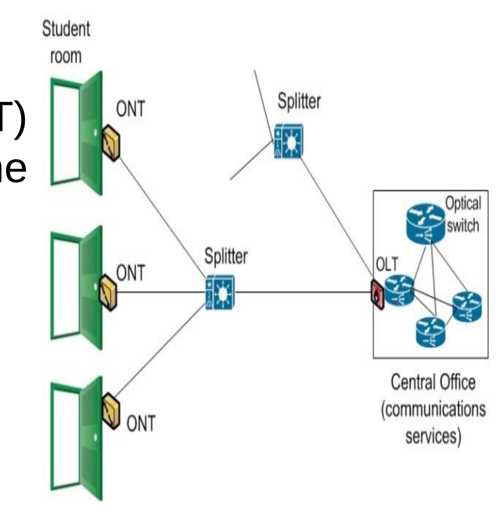


Fig.4. FTTH provisioning

WLAN consumption

Each apartment is provided with a residential gateway. The wireless bandwidth capacity of the gateway is 300 Mbps at 5 GHz rate.

$$P_{WLAN} = N \times (p_t c_t + p_r c_r + p_l c_l + p_s c_s)$$

- $p_t c_t$: probability and consumption in TRANSMIT state
- $p_r c_r$: probability and consumption in RECEIVE state
- $p_l c_l$: probability and consumption in LISTEN state
- $p_s c_s$: probability and consumption in SLEEP state

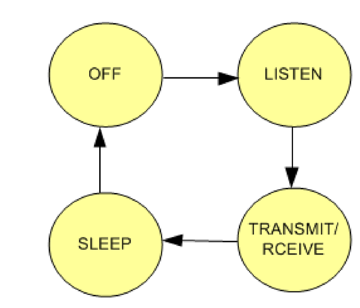


Fig.5. WLAN transition states

Core network consumption

Core switch consumption varies according to the number of active interfaces, the number of subscribers and outgoing links.

- μ: cooling and redundancy factor
- M: traffic requirement
- B: available bandwidth of core switch
- L: the number of the core switches

$$P_{Core} = \mu \times (\sum_{1}^{L} \frac{M}{B} \times \frac{P_{Switch}}{2})$$

MINIMIZING NETWORK FOOTPRINT

Optimal resource planning

The number of splitters and available locations to place the splitters are constraints of the problem.

Determine an optimal plan for placement of splitters and cabling to minimize cable length, the number of networking devices, and total energy consumed to provide broadband services to end-users.

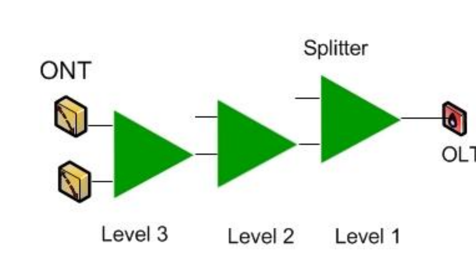


Fig.6. FTTH with multiple splitters

- c_{ij}: cost of connecting user i to splitter j
- d_{ij}: cost of connecting splitter i to splitter j
- $x_{ij} = 1$ iff user i is connected to splitter j
- $y_{ij} = 1$ iff splitter i is connected to splitter j

$$Min \sum_{i=1}^{N} \sum_{j=1}^{M} x_{ij} c_{ij} + \sum_{i=1}^{N} \sum_{j=1}^{M} y_{ij} d_{ij}$$

Optimal wired and wireless network topologies

Since there are fluctuations of user load, network is often planed to support the peak traffic load. This result in overprovisioning during low-load periods.

The objective is to minimize the number of active switch ports and wireless APs while respecting bandwidth requirements.

- p_w, p_t: consumption of switch port and AP
- H, S: sets of APs and switches
- $x_w = 1$ iff the AP w is in active state
- $y_t = 1$ iff the switch port t is in active state

$$Min \sum_{w \in H} x_w p_w + \sum_{t \in S} y_t p_t$$

SIMULATION RESULTS & CONCLUSION

Existing network deployment schemes aim to afford peak load demand, resulting in excessive overprovisioning.

Optimal resource allocation is required to provide sustainability in smart broadband campus

An optimal deployment scheme may reduce over 60% of resource consumption.

Cloud-based smart city is promising to globally optimize environmental impacts.

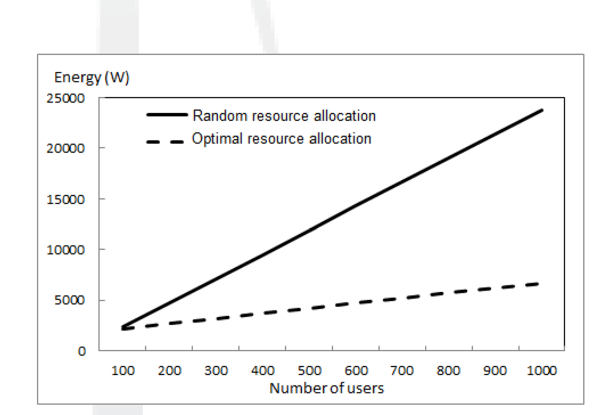


Fig.7. Simulation results of optimal vs. random resource allocations

Our future work will include an integrated framework for environmental assessment of network and cloud computing.

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