Meeting the requirements to deploy cloud RAN over optical networks: elastic optical network resources meet compute resources

Sabidur Rahman

Netlab, UC Davis

krahman@ucdavis.edu

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Introduction

- RRHs can share virtualized BBU pools
- Dynamicity, fine granularity, and elasticity
- Proposed Sliceable Bandwidth-Variable Transponders
- Which COs to place the SBVT to minimize CAPEX and OPEX
- SBVT vs. Fixed Transponders

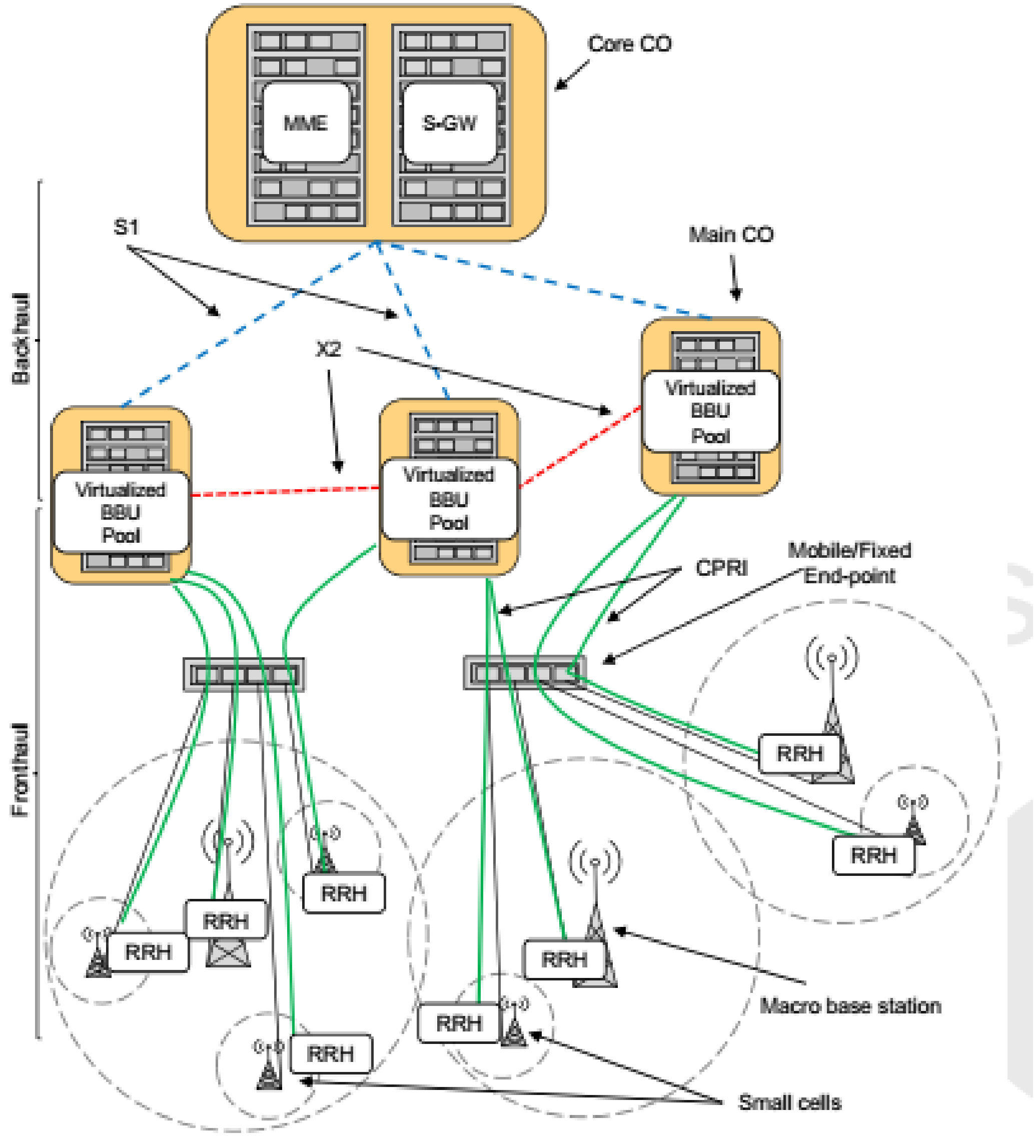


Fig. 2. An example of Cloud RAN architecture.

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Motivation

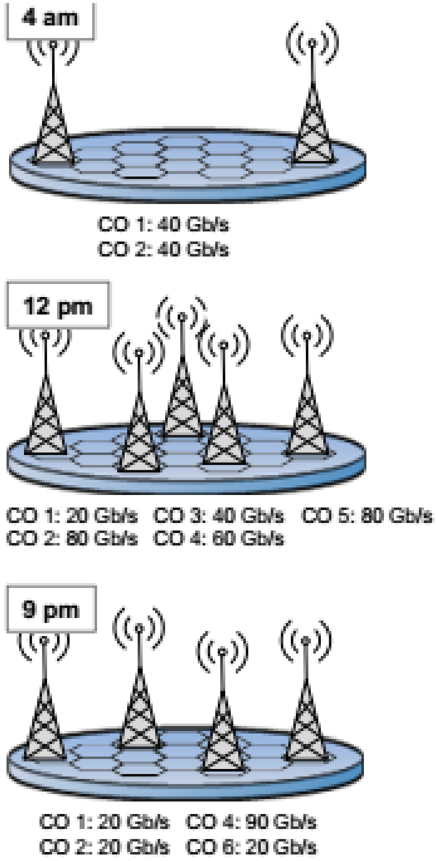


Fig. 3. Connections between COs and core-CO to support S1 interfaces.

C-RAN requires dynamic, elastic, fine granularity from 10Gb/s to 100 Gbps

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Types of Transponders

To interface the optical layer, there are several types of transponders that can be used in both, front and backhaul:

- **Fixed Transponders (FT)** that transmit at a fixed bitrate, e.g., 40Gb/s,
- **Bandwidth-Variable Transponders (BVT)** that can adapt its bitrate up to a maximum capacity e.g., 400Gb/s, and
- **Sliceable Bandwidth-Variable Transponders (SBVT)** that can be shared among a number of optical connections.

SBVT

- Multiple bit rates (10 Gbps to 1 Tbps)
- Dynamically changeable modulation formats
- Sub-channels and super channels allows finer granularity: can avoid the need for grooming
- Redo the DSP of some slices without impacting others
- Dynamic Optical Arbitrary Waveform Generation and Measurement (DOAWG/DOAWM)

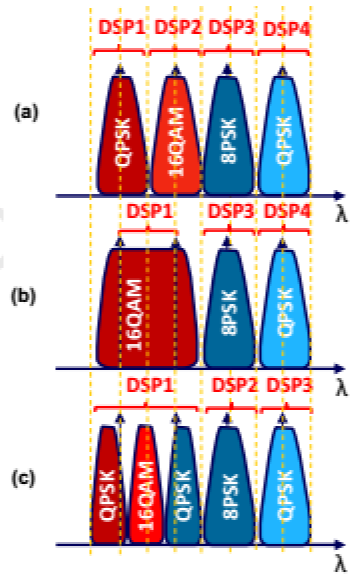


Fig. 4. Examples of multiple channels generated with one DOAWG-based SBVT with four comb-lines (spectral slices).

Number of slices: 4->3->5

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Proposed SBVT Architecture

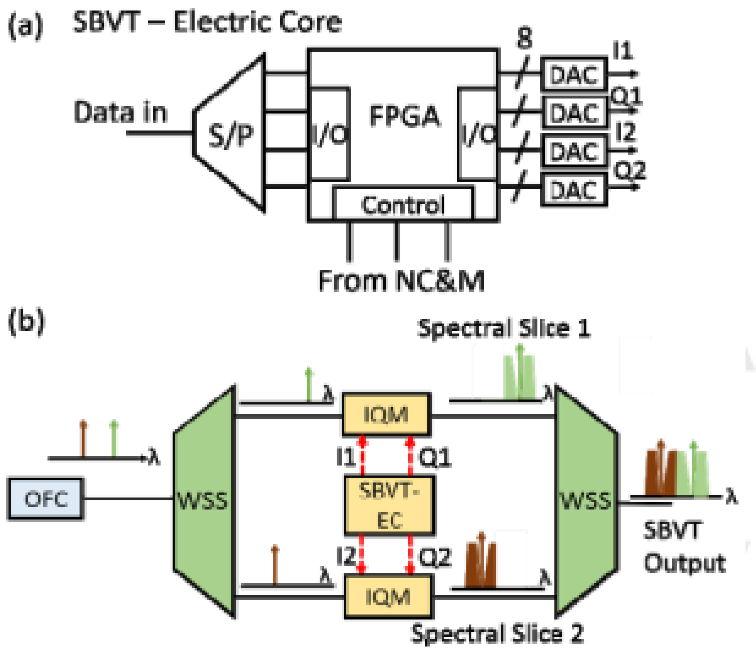


Fig. 5. Schematic diagram of the SBVT (a) and system diagram for two-slice SBVT generation (b).

Electric core: generation of sub- and super- channels
NC&M: how many subchannels? Which modulation format?
Select two tones from the OFC using first WSS
Two Modulators forms two phase-coherent spectral slices
Second WSS combines two slices into large-bandwidth superchannel

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

CRAN CAPEX minimization problem

Given:

- A set of geographically distributed **RRHs** *H*
- The tuple <αh, βh, γh> representing the **required capacity by RRH *h* for CPRI, S1, and X2 interfaces** respectively, pre-computed in advance.
- A set *V* of **VMs' configurations with capabilities for BBU pools** virtualization; each VM configuration *v* is defined by its cost κv and its number of BBUs it can virtualize λv; let us assume that one BBU can serve one RRH
- **A set of transponders *P***; each transponder *p* consists of a set of DSP modules *D*(*p*), where the capacity of each module is φp and its cost κp; since gray or colored transponders may be considered to support the different interfaces, the parameters $\delta pCPRI$, $\delta pS1$, $\delta pX2$ indicate if *p* can support CPRI, S1 or X2 interface links respectively.
- **A set of line cards *C***; each line card *c* can support one type of transponder, and it is defined by its cost κc and the number of ports to plug-in transponders ξcp.
- **A set of MPLS equipment *E***
- **A set *O* with main COs**; each main CO can be equipped with a predefined configuration of VMs and with a MPLS switch.
- *O*(*h*) represents the **subset of main COs that can be reached by RRH *h*** without exceeding delay imposed by CPRI requirements.
- *U*(*o*) accounts for the subset of main COs that can be reached from main CO *o* without violating X2 delay constraints. **Neighbor COs**
- **A core CO with functions for MME, S-GW**, along with others

Output: the VMs' configurations and MPLS equipment, lines cards and transponders to install in each main CO.
Objective: minimize the cost of VMs' configurations, MPLS equipment, line cards and transponders used

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Results(1)

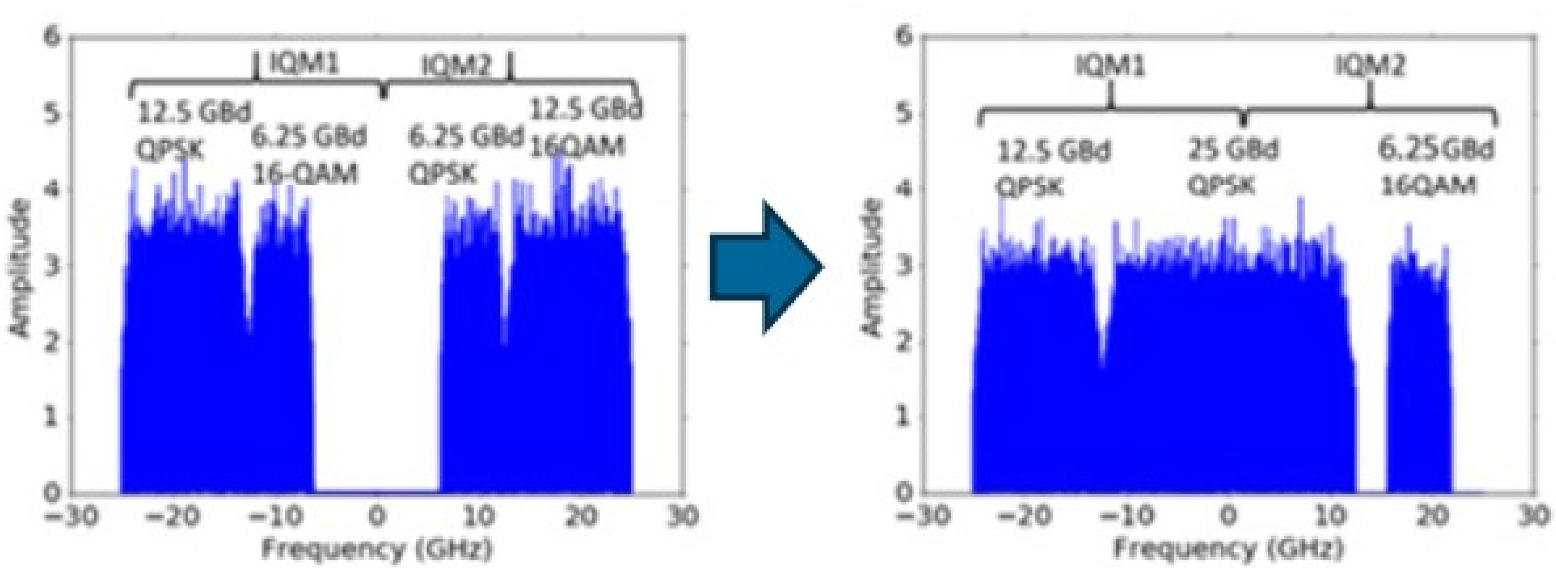


Fig. 9. SBVT reconfiguration from four channels to three channels configuration with one superchannel.

L. Velasco, A. Castro, A. Asensio, M. Ruiz, G. Liu, C. Qin, R. Proietti, and S. J. B. Yoo, "Meeting the requirements to deploy cloud RAN over optical networks." Journal of Optical Communications and Networking, vol. 9, no. 3, pp. 22-32, Feb. 2017.

Results(2)

Take away:
- FTs becomes more costly at higher load
- Higher SVBT capacity saves more cost

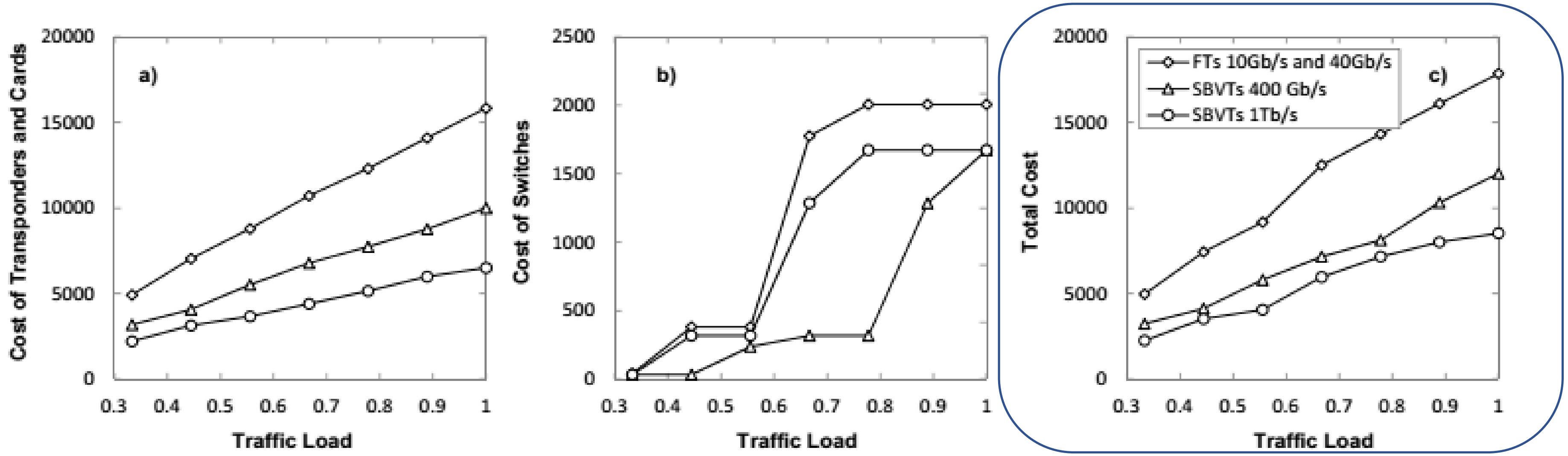


Fig. 11. Transponders (a), Switches (b) and Total cost (c) as a function of the normalized network load when 10Gb/s and 40Gb/s FTs, 400Gb/s, or 1Tb/s SBVTs are installed.

Take away:
- Smaller MPLS switches saves cost

Results(3)

Take away:
Shutting down COs saves power

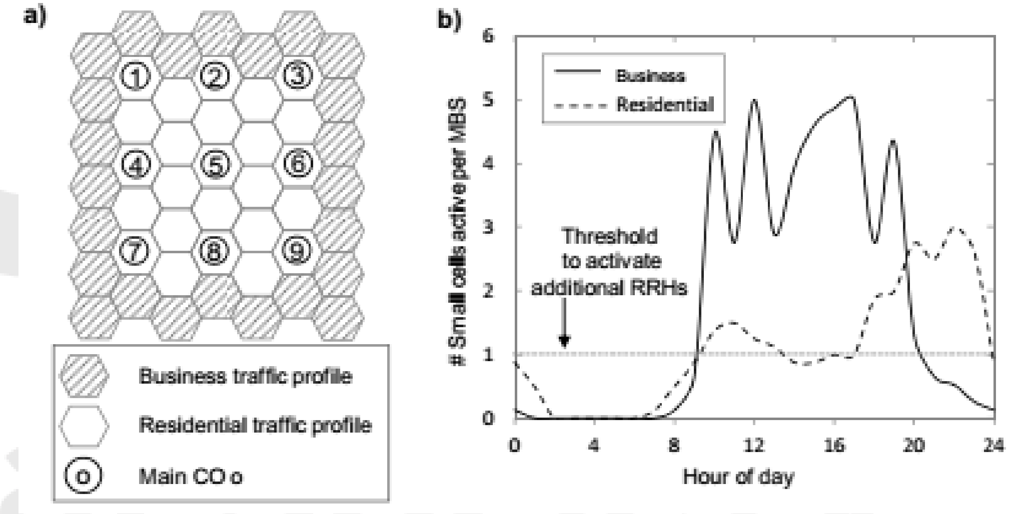


Fig. 10. Cells and main CO placement (a) and number of small cells active, per MBS, against the hour of day (b).

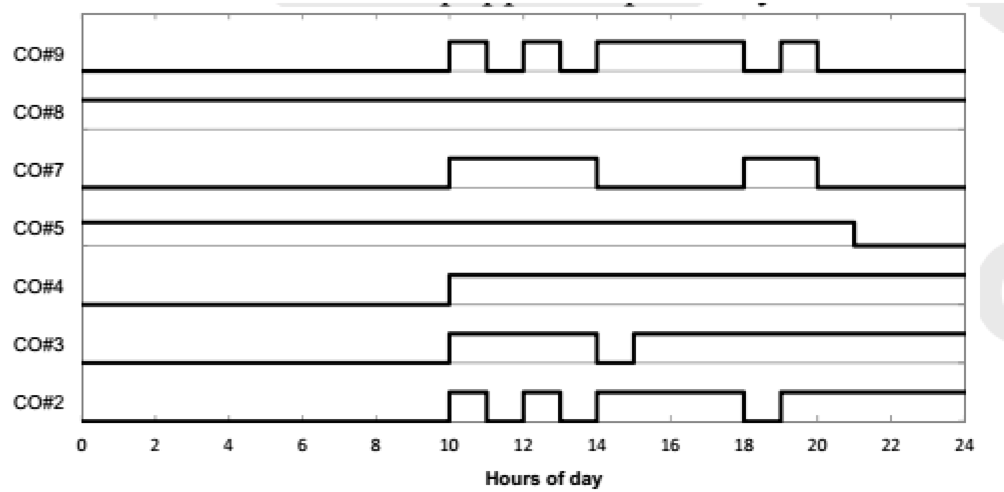
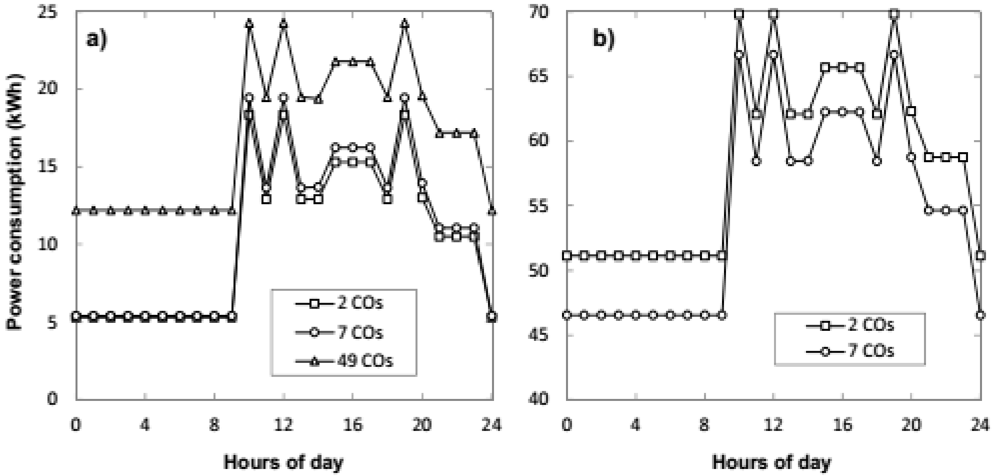


Fig. 13. Main COs to equip against hours of day.



Fi... r consumption of transponders (a) and total equipment (b).

(a) Fully centralized (2CO) lowest number of transponders
(b) 2CO has high power consumption from large switch

Next steps

- Study and evolve to define the problem statement

Thanks!

- Sabidur Rahman
- Netlab, UC Davis
- krahman@ucdavis.edu