DIANA: A Machine Learning Mechanism for Adjusting the TDD Uplink-Downlink Configuration in XG-PON-LTE Systems

Paper Review
Group Meeting Presentation

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P. Sarigiannidis, *et al.*, “DIANA: A Machine Learning Mechanism for Adjusting the TDD Uplink-Downlink Configuration in XG-PON-LTE Systems,” *Mobile Information Systems*, 2017.

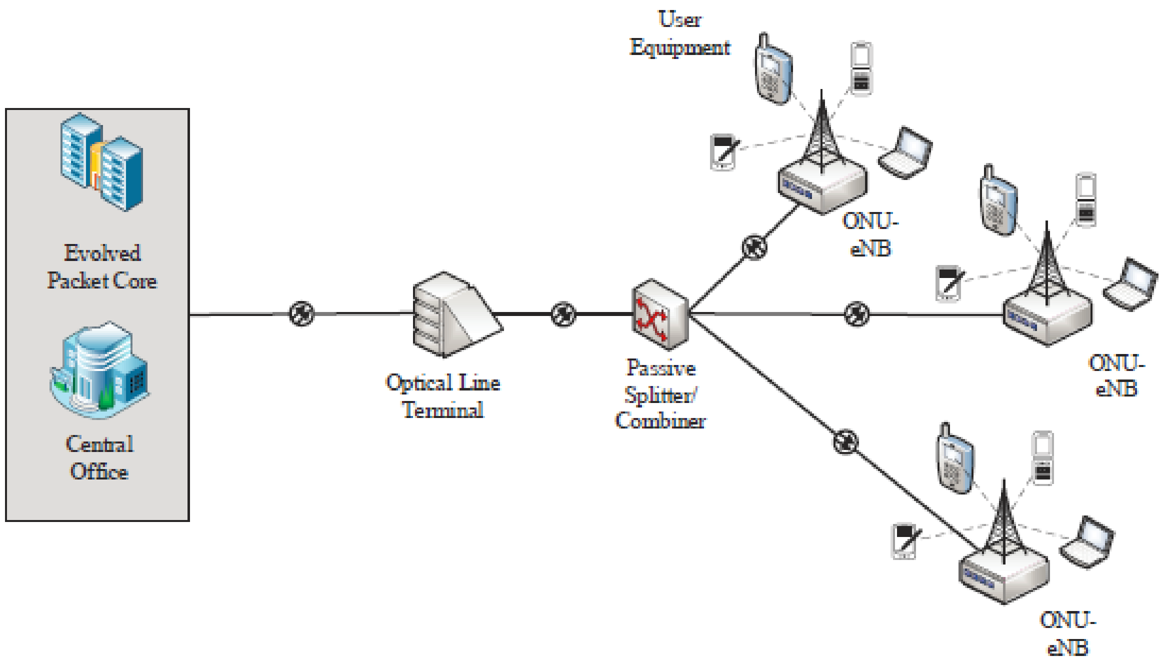
Motivation

- Optical technology offers huge bandwidth and, in case of PONs, a cost-effective solution for creating a lightpath in the access domain.

- On the other hand, 4G technologies, such as LTE and LTE Advanced (LTE-A), exhibit high-speed wireless communication for mobile phones and advanced user terminals (laptops, tablets and smart phones).

- This paper:
  - ✓ Proposes A hybrid (optical/wireless) architecture with the convergence of the two technologies;
  - ✓ Uses SDN capable of collecting and providing traffic-status information;
  - ✓ Adjusts LTE Time Division Duplex (TDD) uplink-downlink configuration based on the information provided by SDN controller using a proposed learning scheme called DIANA;
  - ✓ Reduces latency and jitter.

Hybrid Optical/Wireless Architecture



- XG-PON systems to support 10 Gbps in at least one direction.
- LTE operates in TDD mode.
- Two wavelength are used, one for the upstream transmission at 1270 nm and the other for the downstream transmission at 1577 nm.
- XG-PON downstream/upstream transmission period is 125usec.

SDN Controller

- SDN controller (not shown in figure) manages ONU Management and Control Interface (OMCI) to capture traffic data information in both directions.

- The knowledge obtained by SDN controller is going to be processed, serving to adjust the uplink-downlink configuration in LTE.

- SDN controllers are managed in a distributed way. In other words, each ONU has its own SDN controller.

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DIANA - Time Division Duplex (TDD)

- Standard LTE frame has an overall length of 10 ms, and it consists of 10 sub-frames of length 1 ms each.
- There exist seven uplink-downlink configurations.
- The First and the sixth sub-frames are always for downlink transmission. ‘S’ represents switching. When switching from downlink to uplink, a switching sub-frame is required.

Downlink-to-uplink Configuration	Subframes
0	D-S-U-U-U-D-S-U-U-U
1	D-S-U-U-D-D-S-U-U-D
2	D-S-U-D-D-D-S-U-D-D
3	D-S-U-U-U-D-D-D-D-D
4	D-S-U-U-D-D-D-D-D-D
5	D-S-U-D-D-D-D-D-D-D
6	D-S-U-U-U-D-S-U-U-D

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DIANA – Learning Process

- Summarized in one sentence:
  - ✓ The **real uplink and downlink data transmitted during current LTE frame** collected at the end of the current LTE frame, **together with the data collected for previous LTE frames** can be used to **predict the configuration of next LTE frame**.

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DIANA – Learning Process

- Probability vector of LTE frame *f* at ONU-eNB *i*:

$$P^i(f) = \{p^i_0(f), p^i_1(f), \cdots, p^i_6(f)\}$$

$$\sum_{j=0}^{6} p^i_j(f) = 1$$

$$p^i_j(f) = 1/7, \forall i, j, 1 \leq i \leq N, 0 \leq j \leq 6$$

Downlink-to-uplink Configuration	Subframes
0	D-S-U-U-U-D-S-U-U-U
1	D-S-U-U-D-D-S-U-U-D
2	D-S-U-D-D-D-S-U-D-D
3	D-S-U-U-U-D-D-D-D-D
4	D-S-U-U-D-D-D-D-D-D
5	D-S-U-D-D-D-D-D-D-D
6	D-S-U-U-U-D-S-U-U-D

- Downlink-to-uplink ratio for each configuration:

$$R = \{r_0, r_1, \cdots, r_7\}$$

- Calculate downlink-to-uplink real traffic ratio for LTE frame *f* at ONU-eNB *i* at the end of LTE frame *f*:

$$r^i = r^i_d(f)/r^i_u(f)$$

- Find the closet configuration to the real traffic ratio for current LTE frame *f*:

$$\underset{s}{\text{argmin}} = \{|r^i - r_s|\}$$

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DIANA – Learning Process

Downlink-to-uplink Configuration	Subframes
0	D-S-U-U-U-D-S-U-U-U
1	D-S-U-U-D-D-S-U-U-D
2	D-S-U-D-D-D-S-U-D-D
3	D-S-U-U-U-D-D-D-D-D
4	D-S-U-U-D-D-D-D-D-D
5	D-S-U-D-D-D-D-D-D-D
6	D-S-U-U-U-D-S-U-U-D

- Penalize rest of the configurations:

$$p_j^i(f+1) = p_j^i(f) - W(p_j^i(f) - a), \forall j, 0 \leq j \leq 6, j \neq s$$

W and *a* are learning parameters.

- Reward the closet configuration to the real traffic ratio for current LTE frame *f*:

$$S = W \cdot \sum_{q=0, q \neq s}^{6} (p_q^i(f) - a)$$
$$p_s^i(f+1) = p_s^i(f) + S$$

- Select the configuration with largest probability for the next LTE frame *f+1*:

$$\underset{n}{\operatorname{argmax}} = \{p_n^i(f+1)\}$$

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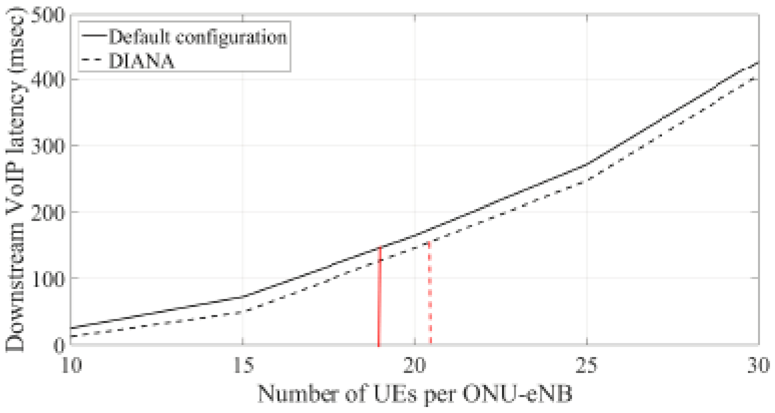
Simulation Setup

- XG-PON-LTE-A network was implemented using the LTE system Toolbox in Matlab.
- OLT is connecting to 8 ONU-eNBs.
- Pure Status Reporting (PSR) scheme was adopted, where each ONU-eNB reports its (uplink) queue occupancy to the OLT to determine the bandwidth allocation.
- $W = 10^{-2}$ and $a = 10^{-4}$.
- Default uplink-downlink configuration was 1.
- In VoIP traffic setting, each UE has a probability of 80% of initializing a VoIP session upon its connection establishment with the corresponding ONU-eNB. The VoIP session generates about 5.5 and 53 Kbps in the upstream and the downstream direction respectively.

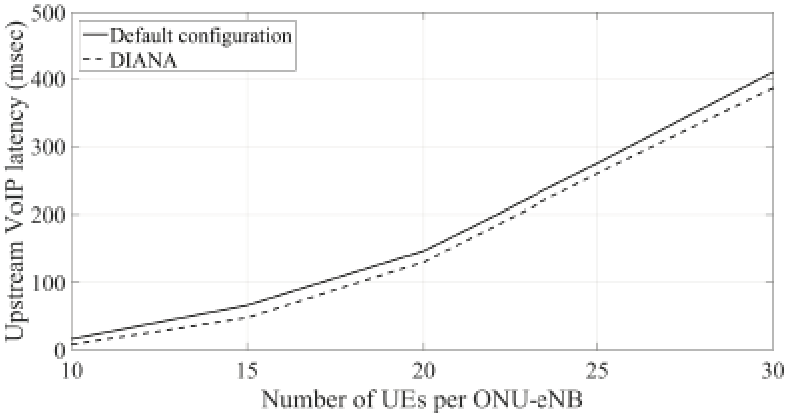
SCENARIO 1: DOWNLINK REFERENCE CHANNEL OPTIONS

Channel Bandwidth	10 Mhz
Allocated Resource Blocks	50
Modulation	16QAM
Target Coding Rate	1/2

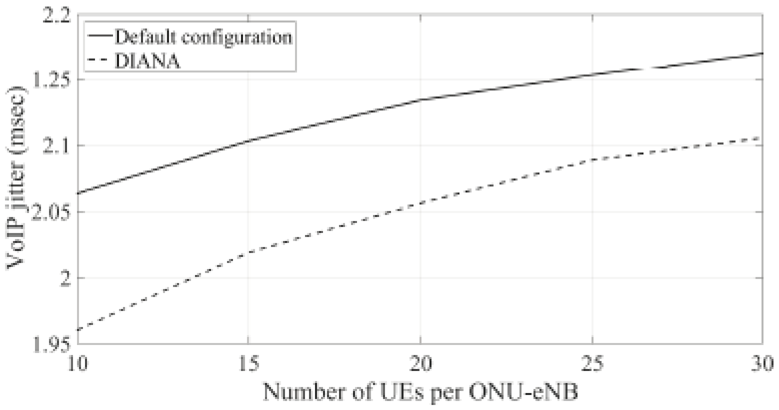
Results



VoIP downstream latency



VoIP upstream latency



VoIP jitter

Thank you!

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