ASEAN IVO FORUM 2016

Energy Efficient NG-PON for Sustainable Green ASEAN Communication Network Infrastructure

Professor Dr Sevia Mahdaliza Idrus

Organisations:

Universiti Teknologi Malaysia, Malaysia.

Tokai University, Japan.

Waseda University, Japan.

Indonesian Institute of Sciences (LIPI), Indonesia.

Universitas Gadjah Mada, Indonesia.

Photonic Network Research Institute, NICT, Japan.

TM Research and Development, Malaysia.

Why Energy Conservation in ICT ?

ICT networks are rapidly expanding and leading to more power generation and thus more power consumption.

- **ITU 2015 report → 46% increase in internet users in last 15 years. (10.8% in fixed broadband and 47% in mobile services subscriptions)[1][3] (Fig.1).**
- **Global Power production increasing. In 2015 recorded as 24000 TWh (Tera Watt hours). [2]**
- **Global electricity generation expected to increase by 69% by 2040 with 36.5 Trillion KWh production and 59% of it from thermal resources (Coal, Natural Gas and Oil). [2]**
- **Electricity generation results in GHG emissions and increase of network maintenance costs [4] contributed to 25% global GCE .**

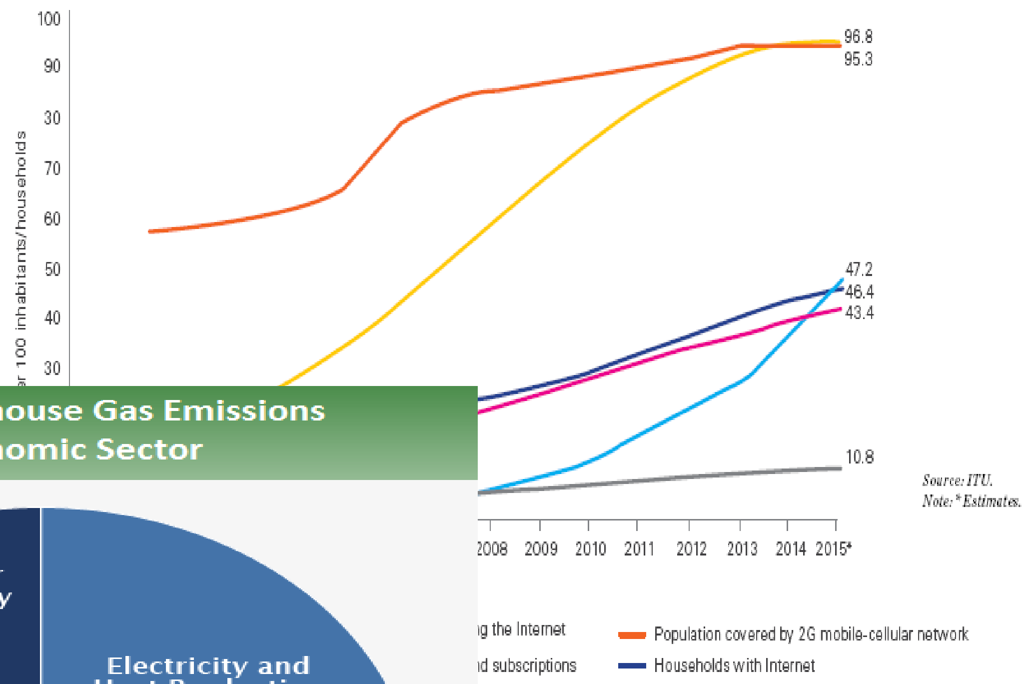


Fig.1: Expansion of ICT network [1]

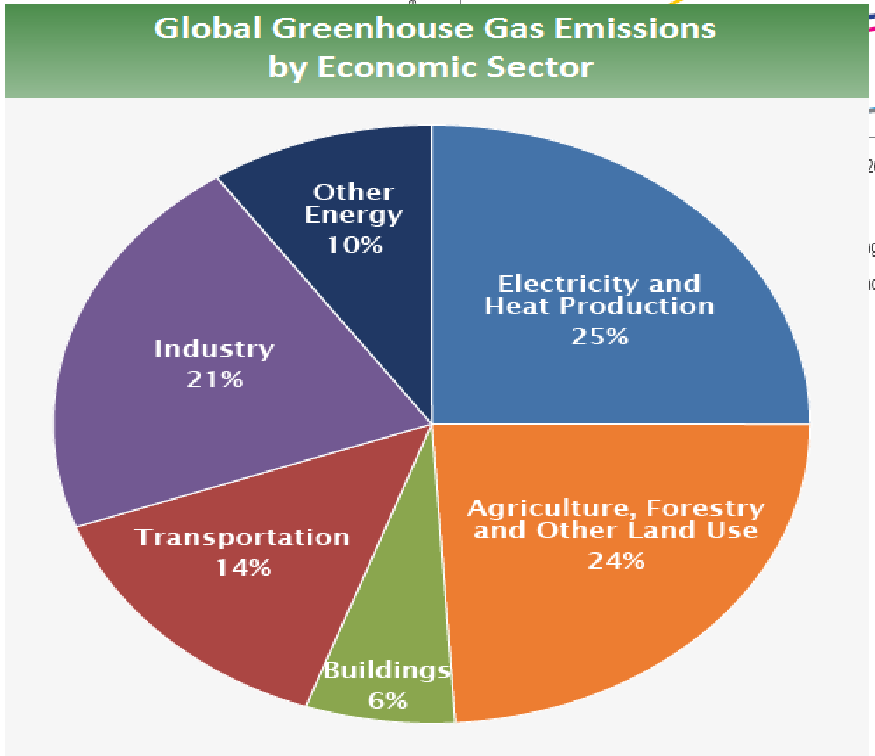


Fig.2 GHG emissions by Sector[39]

Why Energy Conservation in ICT ?

ICT sector responsible for 10% of the global electric power consumption. [5] [6], while [7] study reported it to be 37%.

- The total worldwide electricity consumption in communication networks grew from 200 TWh per year in 2007 to 330 TWh per year in 2012 [8].
- The current carbon foot print of this sector is matching that of the airline industry. [9]
- From 2010 to 2015 the total power consumption in the ICT network was around 20GW! and By 2020 this power consumption is expected to reach 0.2TW and 1.5 TW by 2025. [10]
- Some figures of electricity consumptions and GHG emissions in ICT (Fig.3)

Operational Electricity (TWh) and Total CO_2-eq Emissions (Mt) Relating to Information and Communication Technology (ICT) and Its Subsectors in 2007

ICT	*Operational electricity [TWh]*	*Total CO_2-eq emissions [Mt]*
Mobile telecom	**60**	**80**
Mobile networks, operation	50	46
Mobile networks, manufacturing (incl. also sites, etc.)	n.a.	9
Mobile phones, operation	9	5
Mobile phones, manufacturing	n.a.	21
Fixed telecom	**160**	**120**
Fixed networks, operation	72	54
Fixed networks, manufacturing (incl. also sites, etc.)	n.a.	10
Cordless phones, operation	22	13
BB modems and routers, operation	35	21
PBXs, faxes and various business systems, operation	35	20
End-user telecom equipment, manufacturing	n.a.	6
PCs	**260**	**250**
PCs, operation	258	155
PCs, manufacturing	n.a.	97
Data centers, enterprise networks and transport networks	226	170
Data centers, operation	180	108
Enterprise networks, operation	29	17
Transport networks, operation	17	10
Data hardware, manufacturing	n.a.	30
Total	**710**	**620**

Note: n.a. = not applicable. Operational electricity for manufacturing not assessed. BB = broadband; PBX = private branch exchange.

Fig.3: Power consumption and GHG emissions of [11]

Summary of The Problem

- **70% of the total power of ICT network has been reported to be in the access network. [12]**
- **Passive Optical networks offer an FTTH solution with only two active component at CO (OLT) and user's home (ONU). Due to downstream broadcast in PONs ONUs process frames continuously and thus consume 65% of the overall PON network power while OLT consume only 7%, [13]**
- **Most of the power consumption is in Home Networks (Fig.4). In PON, ONU is the most power hungry device consuming up to 65% power [14].**
- **An energy aware PON equipment can reduce power consumption up to 58% . [15]**

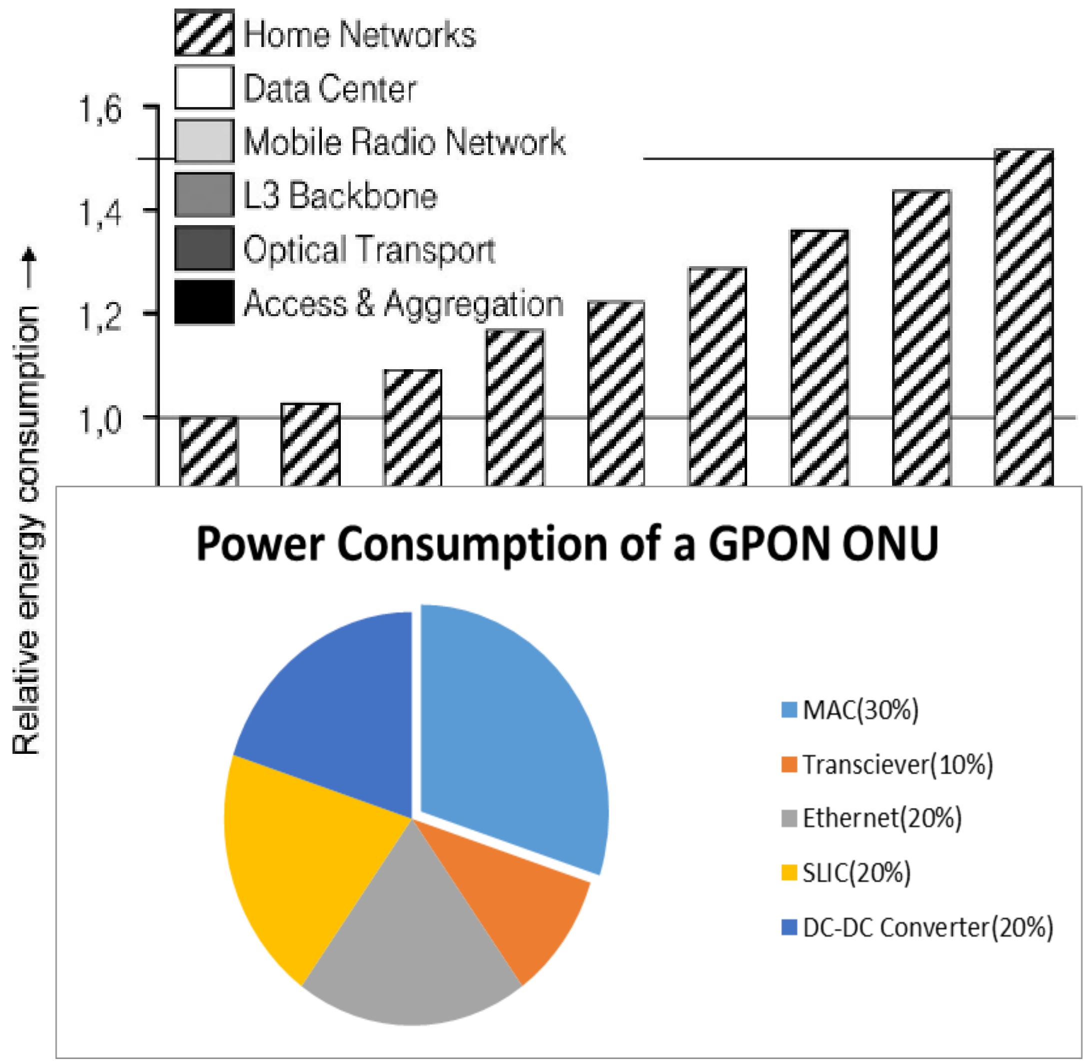


Fig.4 ICT Energy consumption

Energy Efficient Solutions for PON

Energy Efficient PON

- **CDM PON** [15]
- **WDM PON** [16]
- **Improve MAC Layer of TDMA PONs** [21]
  - **EGPON** [17]
  - **Power Shedding** [18,19]
  - **Buffer-less ONUs** [20]
  - **Sleep / Doze Mode**
    - **SPW** [27]
    - **Cyclic Sleep** [43, 44]
      - **FCSM** [28,29]
      - **DCSM** [30,31,32]
      - **ECSM (under research**
    - **Watchful Sleep** [45]
    - **ADAEE** [33]
    - **STM** [34]
    - **Dual Cyclic Sleep** [35]
    - **JIT** [36]
- **Improve Both MAC Layer and Hardware Design for TDMA PONs** [21]
  - **Bi-PON** [21,22]
  - **ALR** [23, 24]
  - **OFDMA PON** [25, 26]

Energy Efficient Solutions for PON

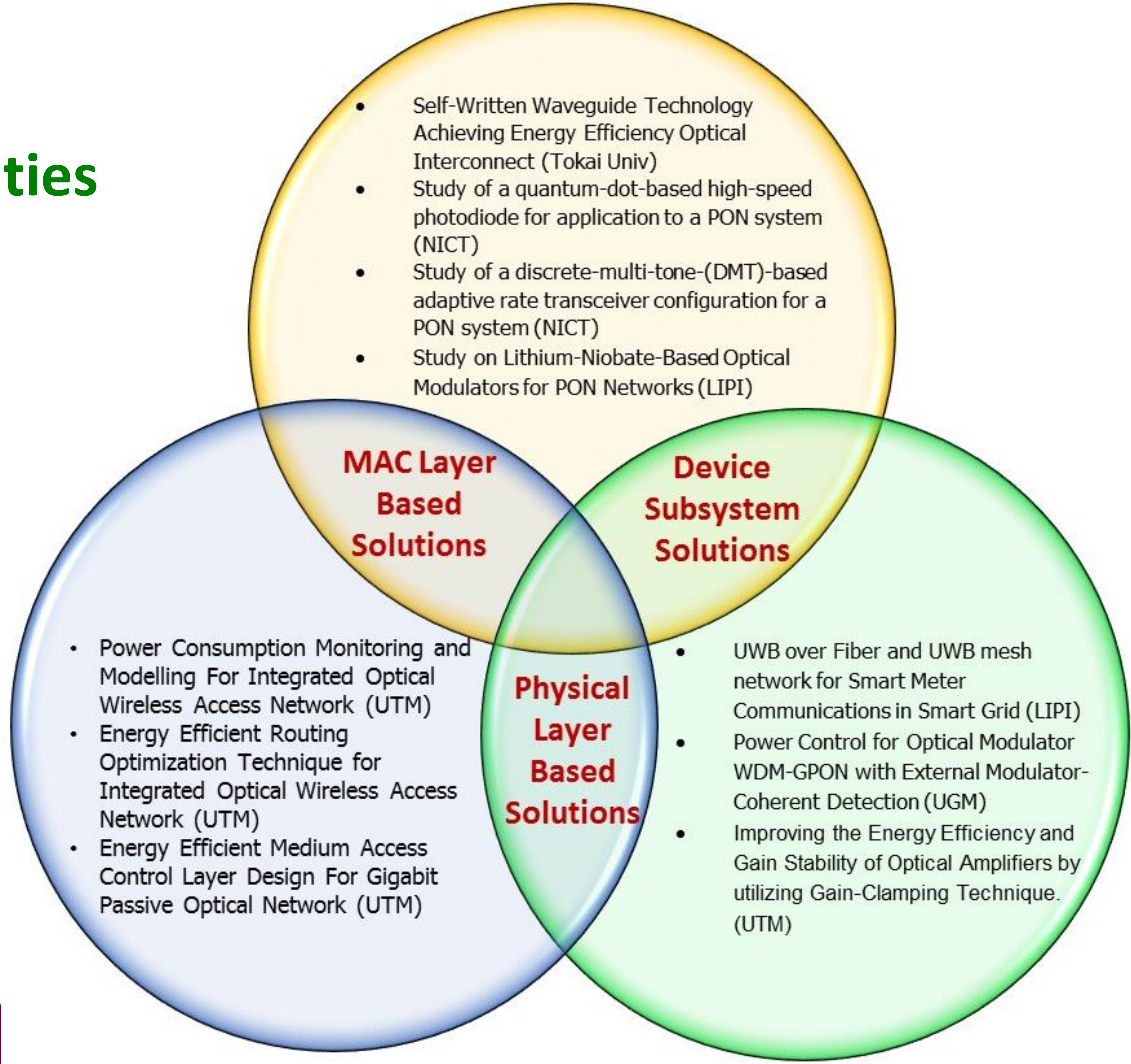
Technique	Key Feature	Drawbacks
DCSM (Dynamic Cyclic Sleep Mode)	• Sleep time is dynamically selected based on traffic arrival rate or queue length. • Many variants of it have been proposed in literature.	Has been reported to be more energy efficient than the FCSM. However, it increases computational complexity of ONU and OLT.
STM (Sleep Transmit Mode)	• Adds an extra Transmit state for ONU to transmit upstream during Sleep cycle	• Reduces Upstream delays but reduces energy savings.
Dual Cyclic Sleep	• Runs cyclic sleep separately for ONU's optical Transmitter (TX) and Receiver (RX). • Turns on on RX after every Ts and turning on TX after 'm' cycles.	• Results in in more power savings compared to cyclic sleep and doze modes. However, the US delay slightly increases due to lesser ON frequency of TX. • More, complicated to implement.
SPW	• OLT controls the sleep mode and instructs the ONU to wake up if there is some traffic arrival at OLT. • OLT computes the sleep time for ONU and sends a sleep message. ONU may reply with a NACK (Negative Acknowledgment) if it has some upstream traffic to send.	• Sleep control depends upon messaging. • This has only been presented for EPON where message reaching the destination may be delayed due to some long traffic burst. • The idea is quite same as of Cyclic Sleep in GPON and XGPON.

Energy Efficient Solutions for PON

Technique	Key Feature	Drawbacks
Power Shedding	• The ONU turns off all the non-essential functions and ports to conserve power, but keeps the optical link operational and fully synchronized. Only the basic voice service is provided during this mode.	• This mode is typically useful during AC power failures as to prolong the life of backup batteries by turning off non-essential functions. • Provides very less energy savings as only non-essential function and user or network interfaces could be turned off and ONU remains in active state.
Watchful Sleep	• Integration of cyclic sleep and cyclic doze modes into one energy conservation mode.	• It has been shown in that Watchful sleep mode is more energy efficient than the cyclic and doze modes while the DS delay is comparatively a little bit higher. However, this work does not consider a DBA scheme and only assumes a single transmission container (TCONT) per ONU. • Still Requires more research.
EGPON	• Proposes new frame structure for GPON to enable ONU only process the related frames and discard the unrelated frames.	• Can only reduce the processing power consumption of an ONU.
Just-in-Time (JIT)	• Proposes a Just-in-Time architecture for ONU to reduce ONU synchronization time from around 2ms to just 64ns. • This enables an OLT to assign sleep slot to an ONU using the	• The proposed architecture has not been practically tested and not commercially adapted by PON standardizing bodies.

Research Direction & Activities

- Advanced research for the green ICT devices, sub-systems, physical and MAC layer for PON infrastructure of the regional telecommunication services.
- The performance of the new energy efficient PON system will be compared with the other competing PONs in terms of its power consumption, deployment cost and Quality of Service.
- Research output will be shared among members in term of joint publications, standardization activities and joint proposal for future works.



Remarks

- Transdisciplinary research works would be an impact to the development of sustainable and energy efficient ICT infrastructure in the region of South East Asia in considering tropical environment.
- Bringing together researchers in the field of optical network technology to promote and encourage more research works on green communication network technology within Asean-IVO members.
- Benefits to both researchers and Telco provider through a comprehensive regional study which later can be referred as a new standard or the findings will be useful inputs to the international standardization bodies such ITU-T/APT.
- The strong advantage of the project is based on existing good collaboration within members under different layers: device, subsystem, networks and standardization. Hence, the proposed project aims is to leverage on existing project facilities and to crowd project equipment resources among IVO-ASEAN members and associates.

Thank You
Arigato Guzaimasu
Terima Kasih

Universiti Teknologi Malaysia, Malaysia (S. M. Idrus, A. S. M. Supa’at, N. Zulkifli, O. Mikami, S. Ambran, A. Hamzah)
Tokai University, Japan (Cheimi Fujikawa)
Waseda University, Japan (Tetsuya Kawanishi)
Indonesian Institute of Sciences (LIPI), Indonesia (Ferdian Yunazar, Yusuf Nur Wijayanto)
Universitas Gadjah Mada, Indonesia. (Adhi Susanto, I Wayan Mustika)
Photonic Network Research Institute, NICT, Japan (Toshi Umezawa, Atsushi Kanno)
TM Research and Development, Malaysia (Romli Mohamad, Shahril Salleh)