Optical Network Design and Planning towards F5G

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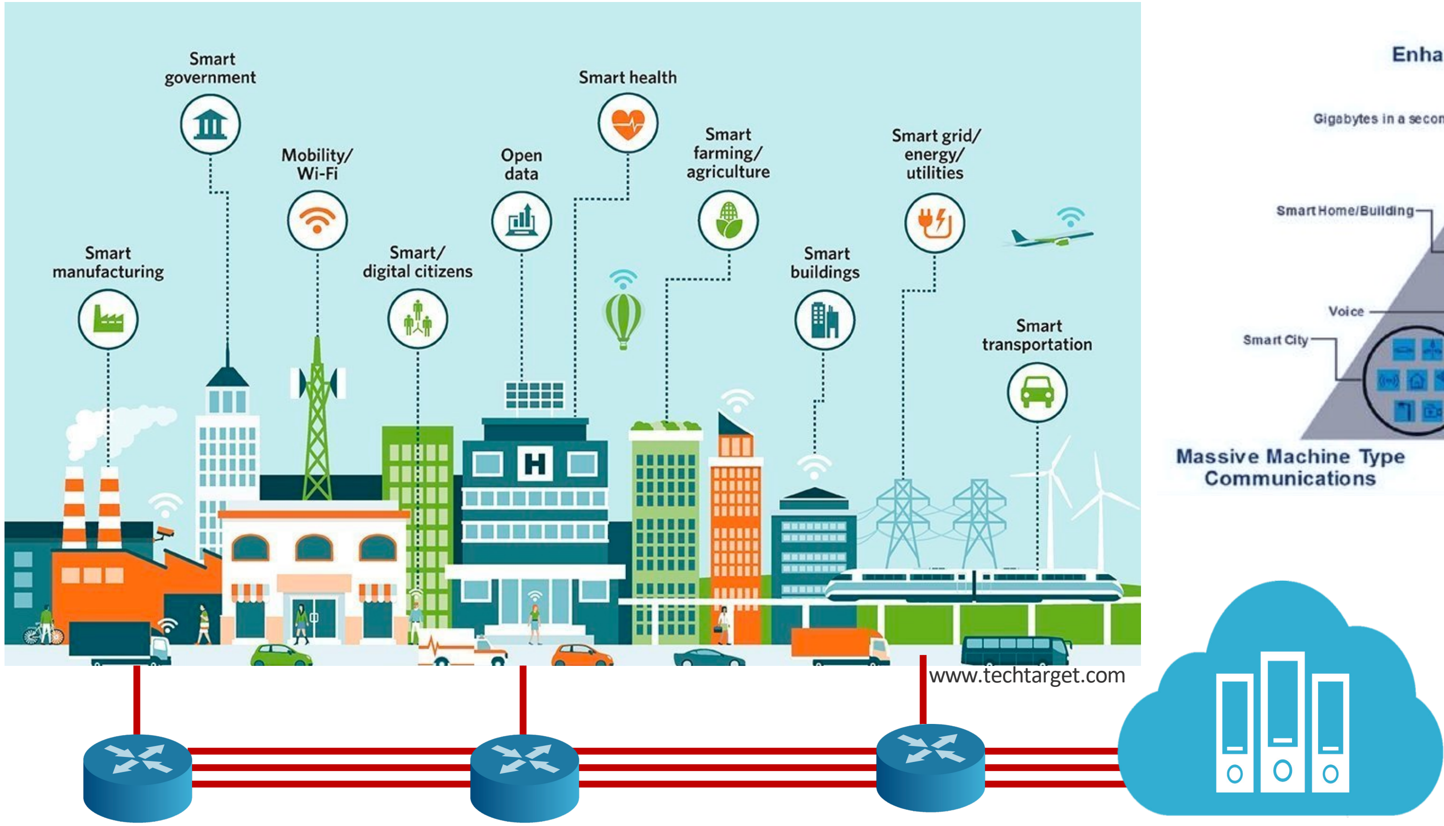
Wireless Evolution

5G: 10-100X data rate improvement, **1000X** bandwidth per unit area, **100%** coverage and **1 ms** latency

6G : support applications such as high-fidelity mobile hologram, truly immersive XR and many more……



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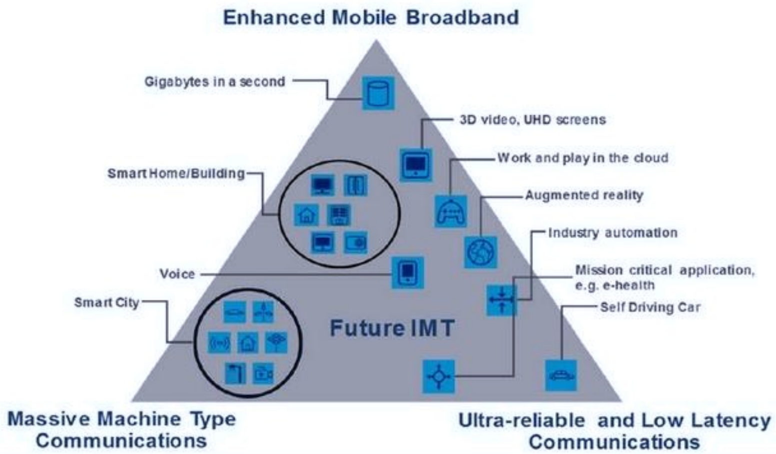

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Why the convergence is important?

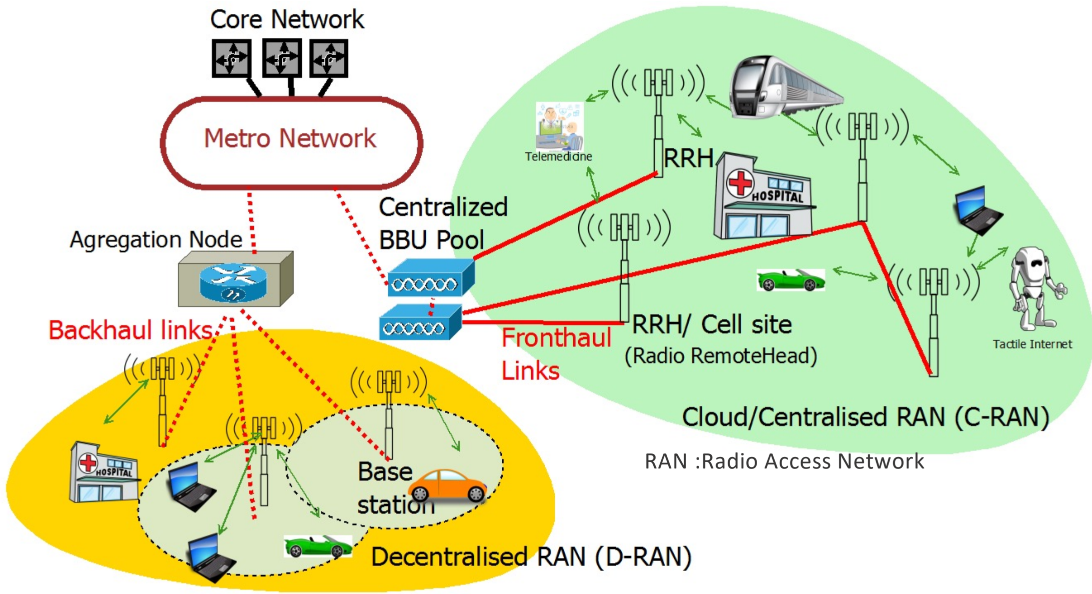
Key Features in 5GB

Massive Scale of Cell Densification

Virtualization

Beamforming

Massive MIMO



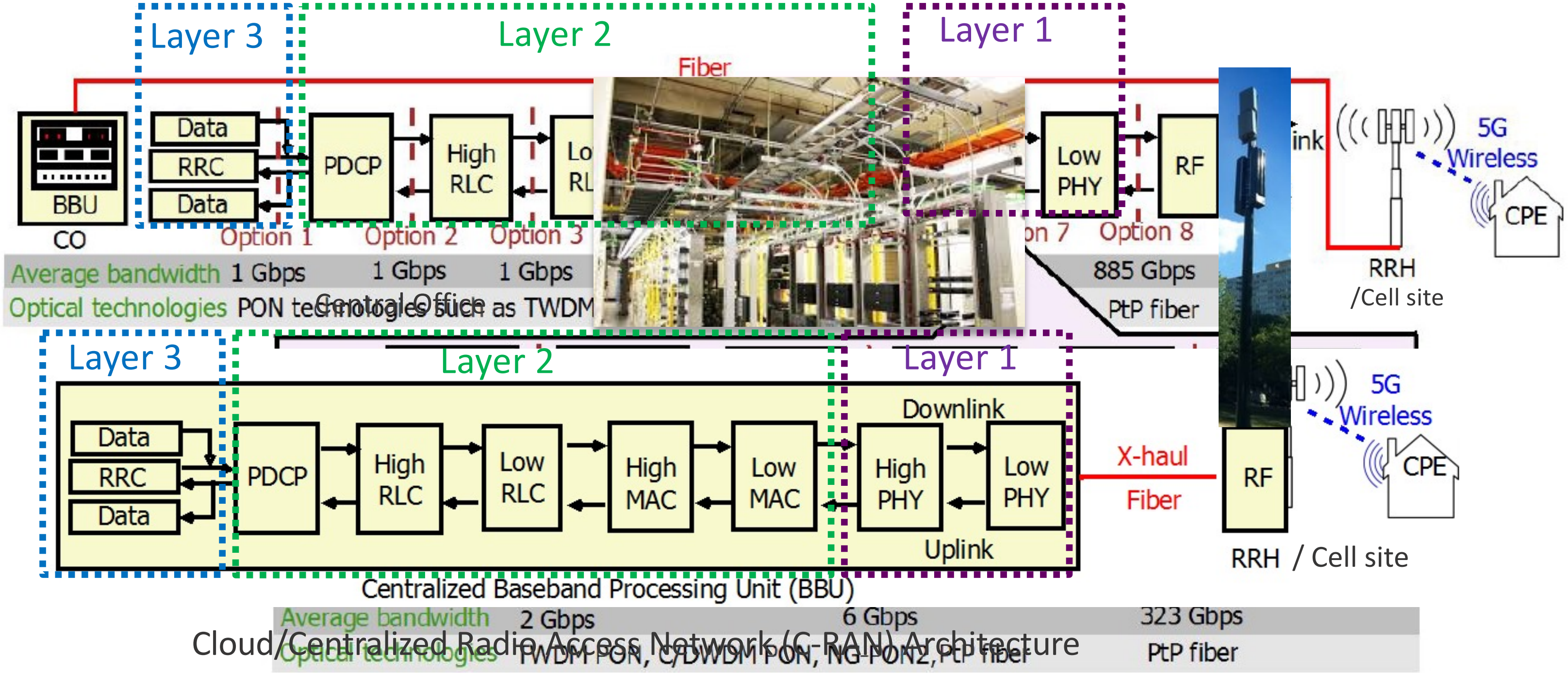
Optical and Wireless Converged Architecture

Network design and planning.

Designs of mechanisms, protocols, algorithm, and architectures to enhance QoS of the converged network

Enhancing the energy efficiency of the network

End to End Access Network Planning



Cloud/Centralized Radio Access Network (C-RAN) Architecture

5G's Transport Network and Functional Split Options

Transport Capacity = $N_A * f_S * 2 N_{Q,td}$ = 96 * (10 * 30.72 MHz) * 2 * 15= **885 Gbps**

where N_A is number of antenna ports; f_S is sample rate; $N_{Q,td}$ is bit resolution in time domain

Optimisation Framework

A generalized framework that can be used

- to jointly plan 5G and its optical transport networks
- in a cost-optimal way (for all functional split options)
- meeting various network requirements such as coverage &capacity
- when we have limited existing fibre network

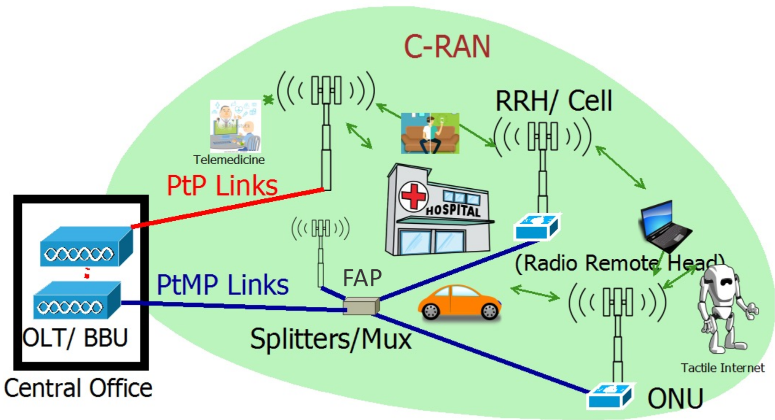
Integer Variables

What we want find:

Optimal locations for

- Cells(RRH)/ONU,
- Splitters/MUXs,
- BBU placements

Optimal fiber routes to deploy the transport network leveraging the resources associated with existing optical access network

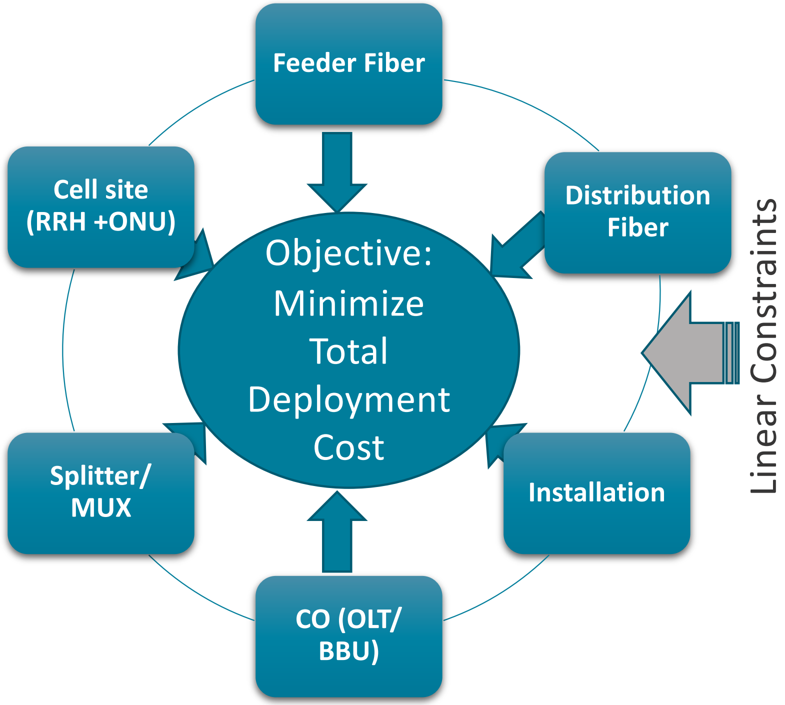


Linear Constraints

Requirements:

- Coverage Requirement
- Limitations of split ratio,
- PtP/PtMP optical connectivity,
- Capacity requirement,
- Number of OLTs &BBUs.

ILP-based Optimisation Framework: Minimize the deployment cost



- Coverage Requirement
- Capacity Requirement
- PtP/PMP optical connectivity
- Limitations of split ratio
- Number of OLTs &BBUs

Objective Function:

$$\min \underbrace{\alpha_{fr}\sum_{i\in\mathbf{C}}\sum_{j\in\mathbf{M}}\tilde{f}_{i,j} + \alpha_{ff}\sum_{i\in\mathbf{C}}\sum_{j\in\mathbf{M}}\tilde{f}_{i,j} * df_{i,j}}_{\text{feeder fiber}} +$$

$$\underbrace{(\alpha_{ft}+\alpha_{fi})\sum_{j\in\mathbf{M}}\sum_{k\in\mathbf{O}} d_{j,k} * dd_{j,k} + \alpha_{fb}\sum_{j\in\mathbf{M}}\sum_{k\in\mathbf{O}}\tilde{d}_{j,k} * dd_{j,k}}_{\text{distribution fiber}}$$

$$+ \underbrace{\alpha_{lc}\sum_{i\in\mathbf{C}}\tilde{y}_i}_{\text{OLT line cards}} + \underbrace{(\alpha_{bb}+\alpha_{bi}+\alpha_{oc})\sum_{i\in\mathbf{C}} x_i}_{\text{BBU \& OLT chassis}} +$$

$$\underbrace{(\alpha_{ot}+\alpha_{fc})\sum_{j\in\mathbf{M}}\tilde{s}_j}_{\text{cost per connection at CO}} + \underbrace{\alpha_{si}\sum_{j\in\mathbf{M}} s_j + \alpha_{ss}\sum_{j\in\mathbf{M}}\tilde{s}_j}_{\text{splitters/MUX}} +$$

$$\underbrace{(\alpha_{on}+\alpha_{rr})\sum_{k\in\mathbf{O}}\tilde{r}_k + \alpha_{ri}\sum_{k\in\mathbf{O}} r_k}_{\text{ONU \& RRH}} \qquad (1)$$

Constraints:

1) Coverage Requirement:

$$\sum_{l\in\mathbf{H}} h_l \geq p_c * n_B/100$$

$$h_l \leq \sum_{k\in\mathbf{O}} t_{k,l} * r_k, \ \forall l \in \mathbf{B}$$

$$h_l \geq \sum_{k\in\mathbf{O}} t_{k,l} * r_k/bigM,$$

Optimization Framework : ILP-based

Objective Function:

$$\min \underbrace{\alpha_{fr}\sum_{i\in\mathbf{C}}\sum_{j\in\mathbf{M}}\tilde{f}_{i,j}+\alpha_{ff}\sum_{i\in\mathbf{C}}\sum_{j\in\mathbf{M}}\tilde{f}_{i,j}*df_{i,j}}_{\text{feeder fiber}}+$$

$$\underbrace{(\alpha_{ft}+\alpha_{fi})\sum_{j\in\mathbf{M}}\sum_{k\in\mathbf{O}}d_{j,k}*dd_{j,k}+\alpha_{fb}\sum_{j\in\mathbf{M}}\sum_{k\in\mathbf{O}}\tilde{d}_{j,k}*dd_{j,k}}_{\text{distribution fiber}}$$

$$+\underbrace{\alpha_{lc}\sum_{i\in\mathbf{C}}\tilde{y}_i}_{\text{OLT line cards}}+\underbrace{(\alpha_{bb}+\alpha_{bi}+\alpha_{oc})\sum_{i\in\mathbf{C}}x_i}_{\text{BBU \& OLT chassis}}+$$

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$$h_l\leq\sum_{k\in\mathbf{O}}t_{k,l}*r_k,\ \forall l\in\mathbf{B}$$

$$h_l\geq\sum_{k\in\mathbf{O}}t_{k,l}*r_k/bigM,\ \forall l\in\mathbf{B}$$

2) Capacity Requirement:

$$\tilde{r}_k*c_r\geq c_h*\sum_{l\in\mathbf{B}}z_{k,l},\ \forall k\in\mathbf{O}$$

$$\sum_{k\in\mathbf{O}}z_{k,l}\geq h_l,\ \forall l\in\mathbf{B}$$

$$z_{k,l}\leq t_{k,l},\ \forall k\in\mathbf{O},\forall l\in\mathbf{B}$$

3) Point to Multipoint Deployment:

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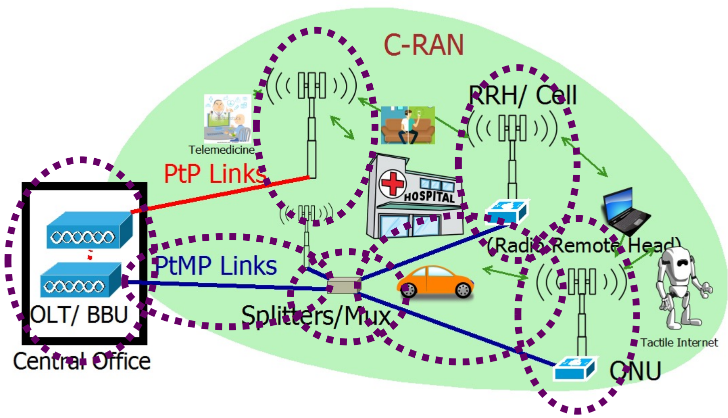


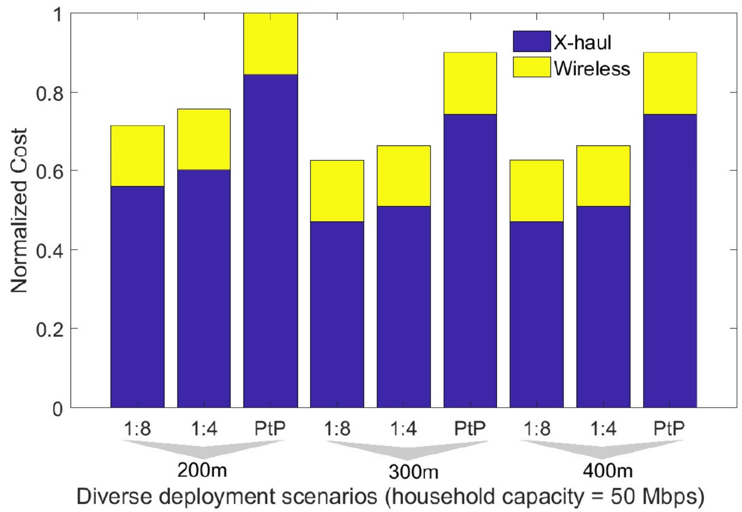
Optical Transport Network Design for 5G Fixed Wireless Access", in IEEE/OSA Journal of LightwaveTechnology, 2019.

Data Set and Optimal Solution

(a)

Cell locations (Intersection) CO location Fiber Access Points

Some More Results

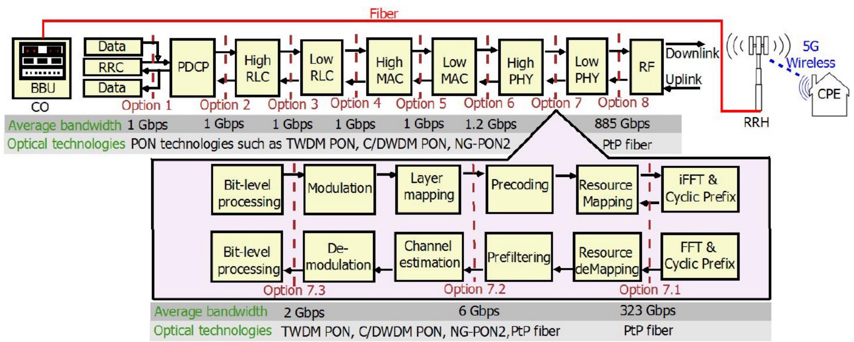


Optimal cost when 10G WDM PON and PtP used as a transport network with coverage 99%

Optical transport = X-haul

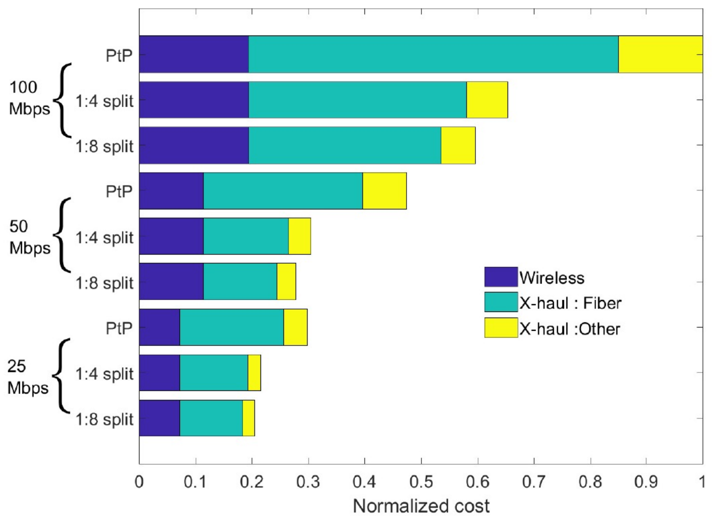
Example: Cost Components used For 10G WDM-PON

Cost component	Notation	Normalized Cost
Existing fiber /km	α_{ff}	41.6
Distribution fiber/ km	α_{fd}	10.4
Fiber trenching/ km	α_{ft}	93.7
Testing per fiber	α_{fr}	1
OLT chassis (16 slots)	α_{oc}	118.75
OLT line card (16X10G)	α_{lc}	13.3
Optical transceiver	α_{ot}	3.6
CO connection	α_{fc}	3.1
MUX/DMUX (1:8)	α_{si}	3.3
ONU	α_{on}	4.7
RRH	α_{rr}	20.8
BBU	α_{bb}	729.1

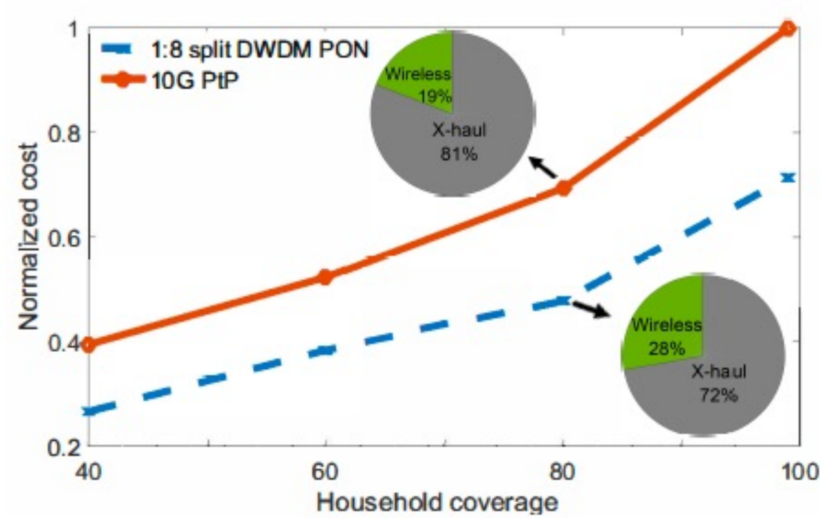


Functional Split Options

Some More Results



Optimal Cost : 10G WDM PON and PtP with 200m cells



Optimal Cost Vs. Coverage requirement

Functional Split Options from 1-6 can save 30-40% of deployment cost compared to Option 7.2.

Summary

We have looked at:

How we can bring the benefits of both optical and wireless access technologies together to enable a cost-effective deployment of gigabit wireless access.

How we can optimally plan the both optical and wireless networks to satisfy diverse network requirements whilst minimizing the deployment cost.

Insight:

Provide insight into the network design strategies that can be used in planning and dimensioning of future optical- wireless networks.

Big Thank Goes to…

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Thank You!
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