Green Mobile Backhaul in Heterogeneous Wireless Deployments

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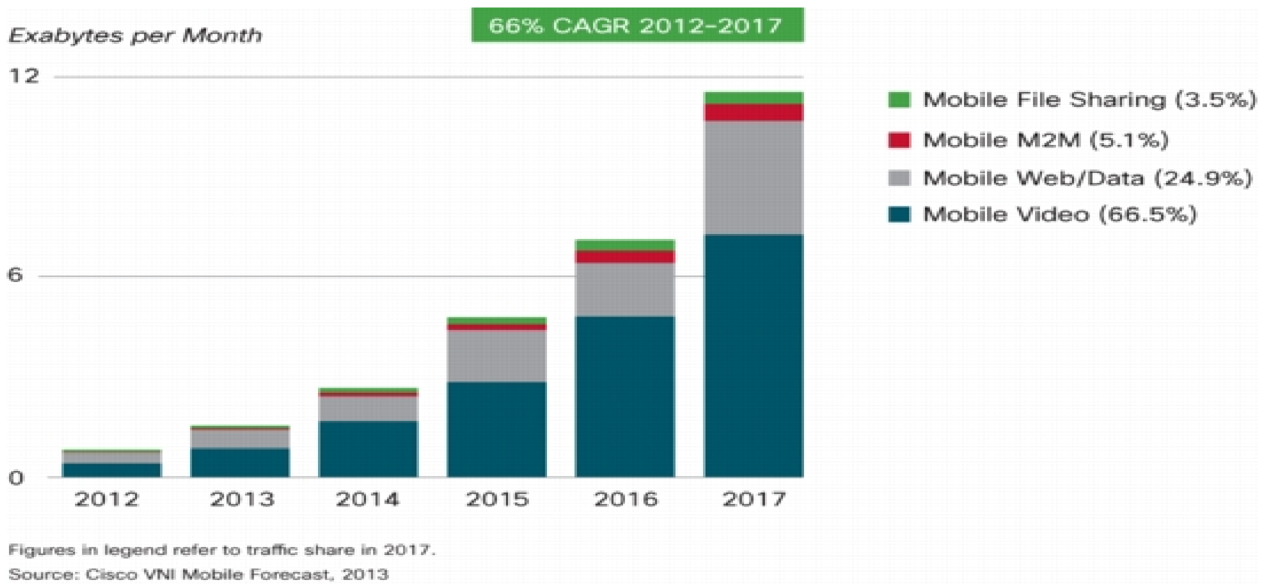
Outline

- HetNet deployment and role of BH
- Case study with different HetNet solutions
  - Macro BS + pico BS: outdoor deployment
  - Macro BS + femto BS: indoor deployment
- BH power consumption assessment
- Conclusions

Energy efficiency becoming a priority in mobile broadband access

- Mobile broadband data usage is experiencing a dramatic growth



- Power consumption will increases to keep up with traffic demand
- Energy prices increase (expected: 3x in 7 years)
- Clear challenge ahead: meeting the expected 2020-2025 traffic levels maintaining current/low power consumption figures

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Possible solution: HetNet deployments

- HetNet is an alternative to macro cell densification
- Rationale: tailor network deployment to the expected traffic levels
  - selectively add small high-capacity BS only where it is needed (hotspots)
- Result
  - smaller cell sizes (advantageous path loss)
  - capacity provided by macro cells
  - coverage provided by Pico/Micro/Femto BS

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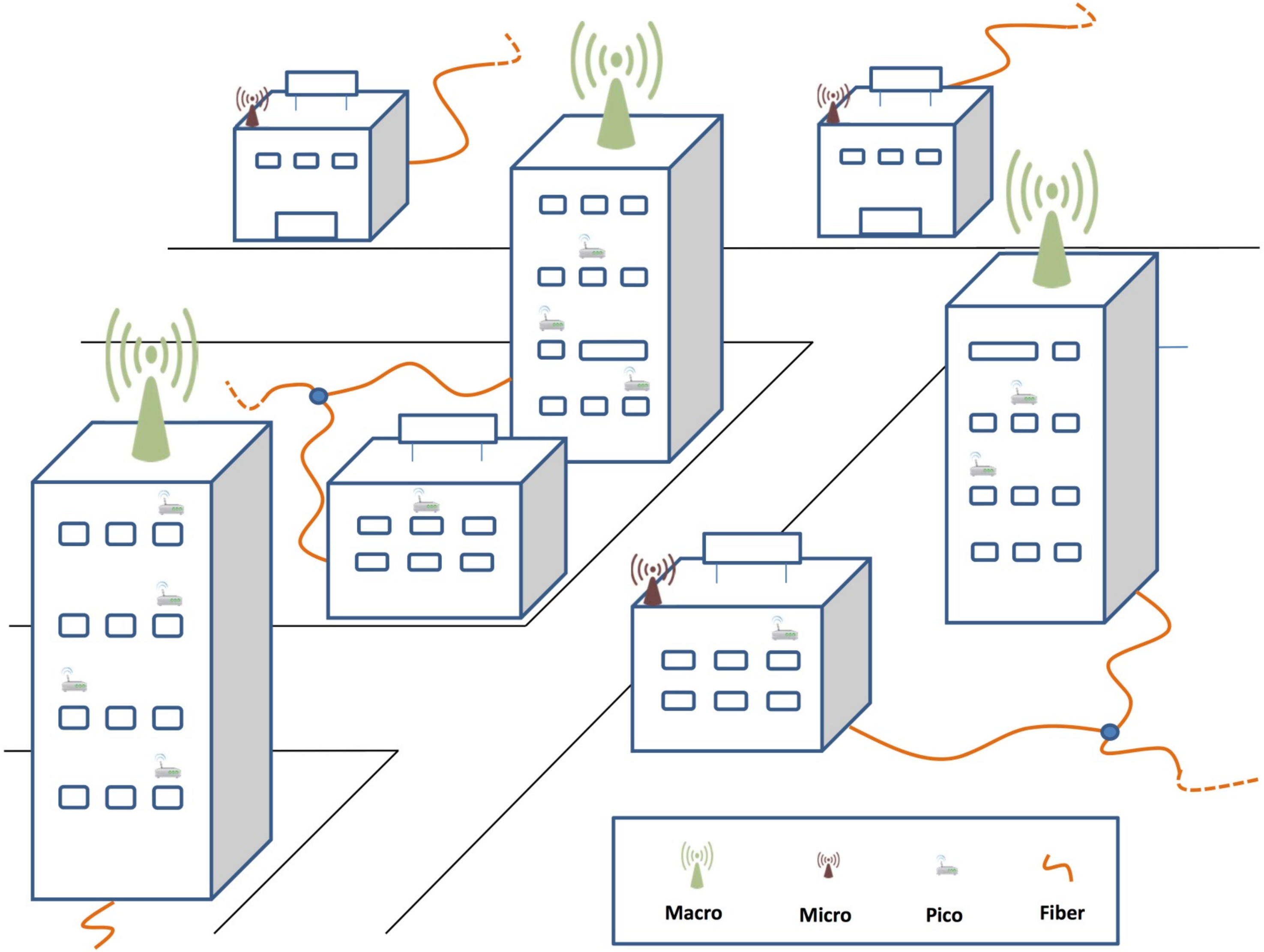
HetNet deployment – an example



HetNet: role of backhaul unclear

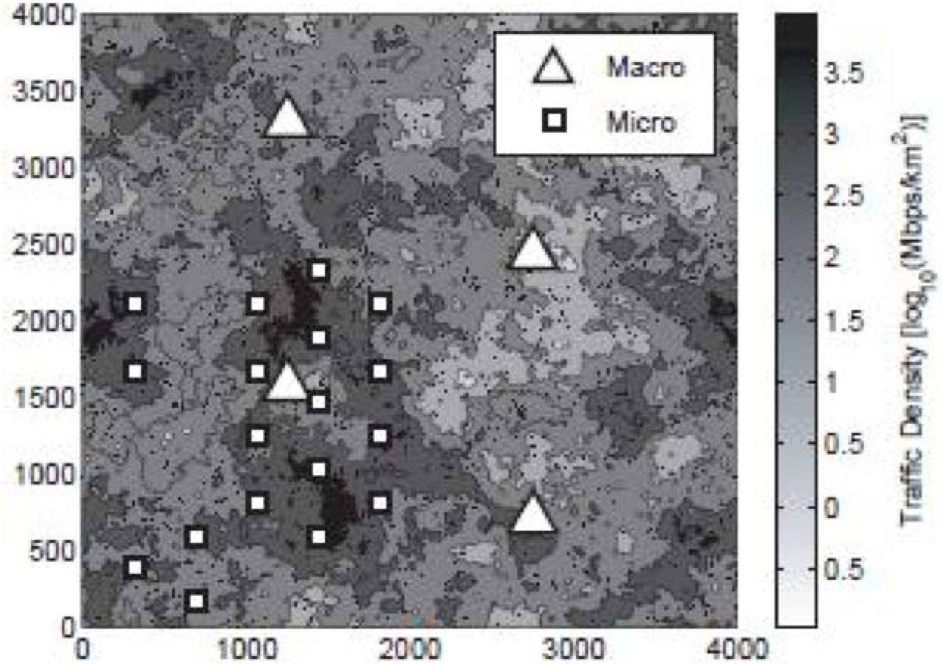
- Most studies consider only the aggregated power consumption of the base stations
- Contribution of the backhaul to the total network power is omitted/neglected
- Analysis of the power consumption for HetNet deployment scenarios including the effect of BH is needed
- Two HetNet case studies are considered:
  - macro + pico: outdoor deployment
  - macro + femto: indoor deployment

Case study: HetNet outdoor deployment

Cost (i.e., $) effective HetNet deployment for a area of 4 × 4km with 3G UMTS macro and pico BS

- Each BS type assumed to have
  - maximum supported throughput s_{max} [Mbps/km2]
  - maximum range δmax [km]
- Number of base stations required is determined sequentially
  - macros are deployed first to provide coverage
  - picos added where extra capacity needed
- Two BH technologies: MW and fiber

- Peak user downstream data rate of 100Mbps in total



K. Johansson, "Cost effective deployment strategies for heterogeneous wireless networks," *Ph.D. dissertation*, Sweden, November, 2007, KTH Information and Communication Technology

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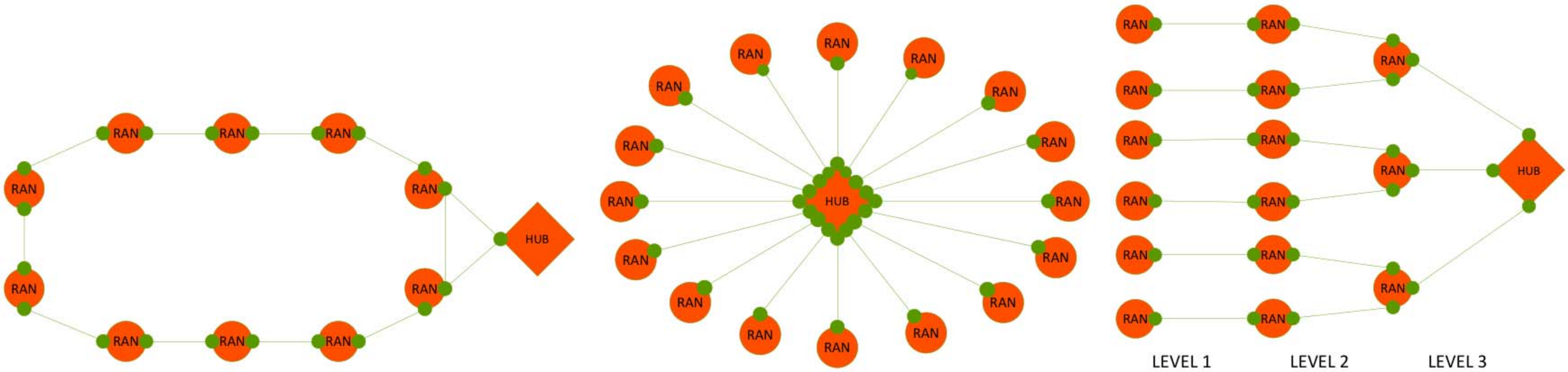
MW-based backhaul architectures



- Traffic backhauled through a *hub* node connected to an area aggregation point, i.e., *sink* node
- Single/multiple hubs, function of topology and architectural choice
- If multiple backhaul links originates or terminate at a node, *switch* is needed
- *Ring*: good for resiliency, latency might me an issue, limited number of sites because of capacity issues
- *Star*: simplest one, might have LOS limitation for MW links
- *Tree*: sensitive to faults to feeder links, better delay than ring

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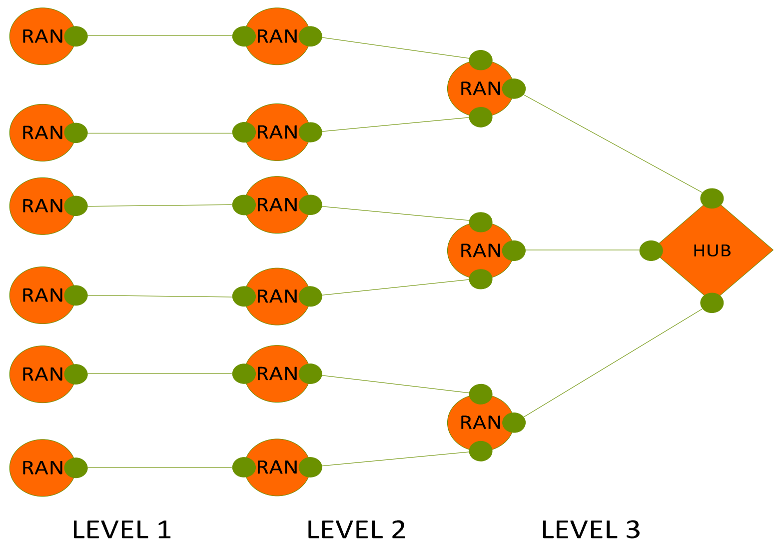
MW-based backhaul power model

$$P_{tot}^{MW} = \sum_{i=1}^{m} N_i P_i + P_{bh}^{MW}$$

$$P_i = a_i P_{tx} + b_i$$

$$P_{bh}^{MW} = P_{\text{sink}} + \sum_{j=1}^{N_{BS}} P_j^{MW}$$

$$P_j^{MW} = P_{j,agg}(C_j) + P_{switch}(N_j^{ant}, C_j)$$



$$P_{j,agg}(C_j) = \begin{cases} P_{low-c}, & \text{if } C_j \le Th_{low-c} \\ P_{high-c}, & \text{otherwise} \end{cases};$$

$$P_{j,switch}(N_j^{ant}, C_j) = \begin{cases} 0, & \text{if } N_j^{ant} = 1 \\ P_S * \left\lceil \frac{C_j}{C_{switch}^{MAX}} \right\rceil, & \text{otherwise} \end{cases}$$

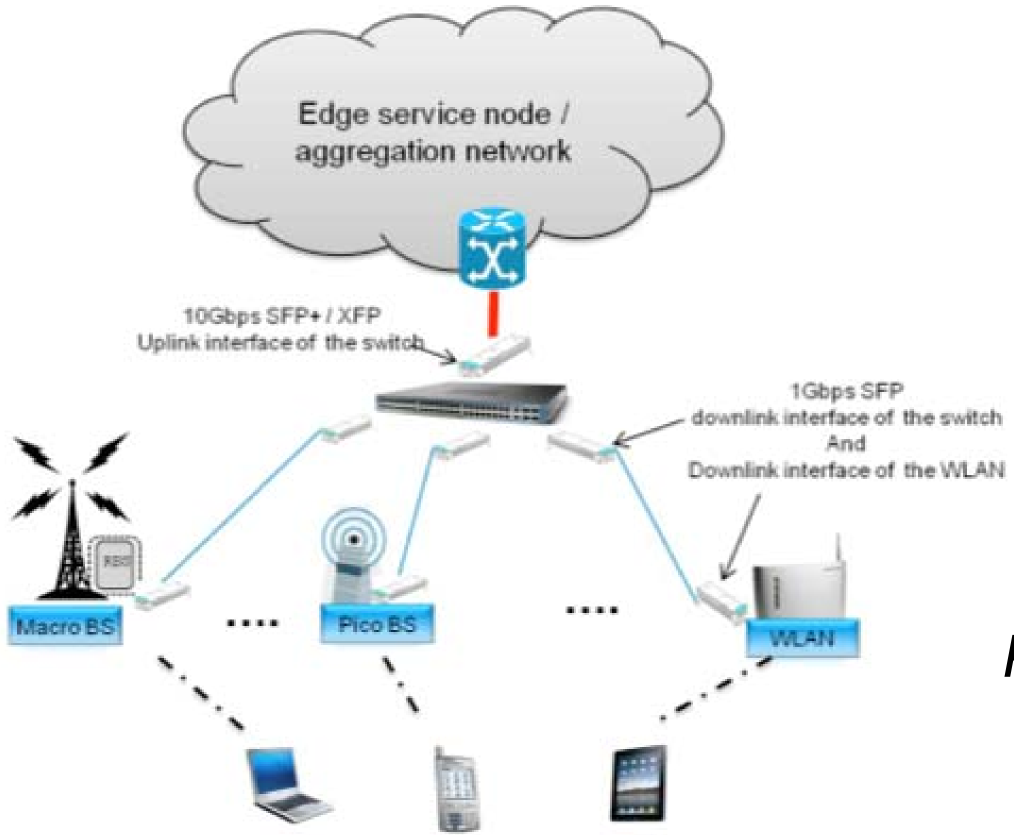
$$P_{\text{sink}} = P_{\text{sink},agg}(C_{\text{sink}}) + P_{\text{sink},switch}(N_{\text{sink}}^{ant}, C_{\text{sink}})$$

$$P_{\text{sink},agg}(C_{\text{sink}}) = \begin{cases} P_{low-c}, & \text{if } C_{\text{sink}} \le Th_{low-c} \\ P_{high-c}, & \text{otherwise} \end{cases};$$

$$P_{\text{sink},switch}(N_{\text{sink}}^{ant}, C_{\text{sink}}) = \begin{cases} 0, & \text{if } N_{\text{sink}}^{ant} = 1 \\ P_S * \left\lceil \frac{C_{\text{sink}}}{C_{switch}^{MAX}} \right\rceil, & \text{otherwise} \end{cases}$$

P. Monti, S. Tombaz, L. Wosinska, J. Zander, "Mobile Backhaul in Heterogeneous Network Deployments: Technology Options and Power Consumption," in Proc. **IEEE ICTON**, 2012

Fiber-based backhaul topology and power model



$$P_{tot}^{FIB} = \sum_{i=1}^{m} N_i P_i + P_{bh}^{FIB}$$

$$P_i = a_i P_{tx} + b_i + c_i$$

$$P_{bh}^{FIB} = \left\lceil \frac{1}{C_{switch}^{MAX}} \left(\sum_{i=1}^{m} C_i \right) \right\rceil P_s + \left(\sum_{i=1}^{m} N_i \right) P_{dl} + N_{ul} P_{ul}$$

S. Tombaz, et al., "Impact of Backhauling Power Consumption on the Deployment of Heterogeneous Mobile Networks," *in Proc.* ***IEEE GLOBECOM***, 2011

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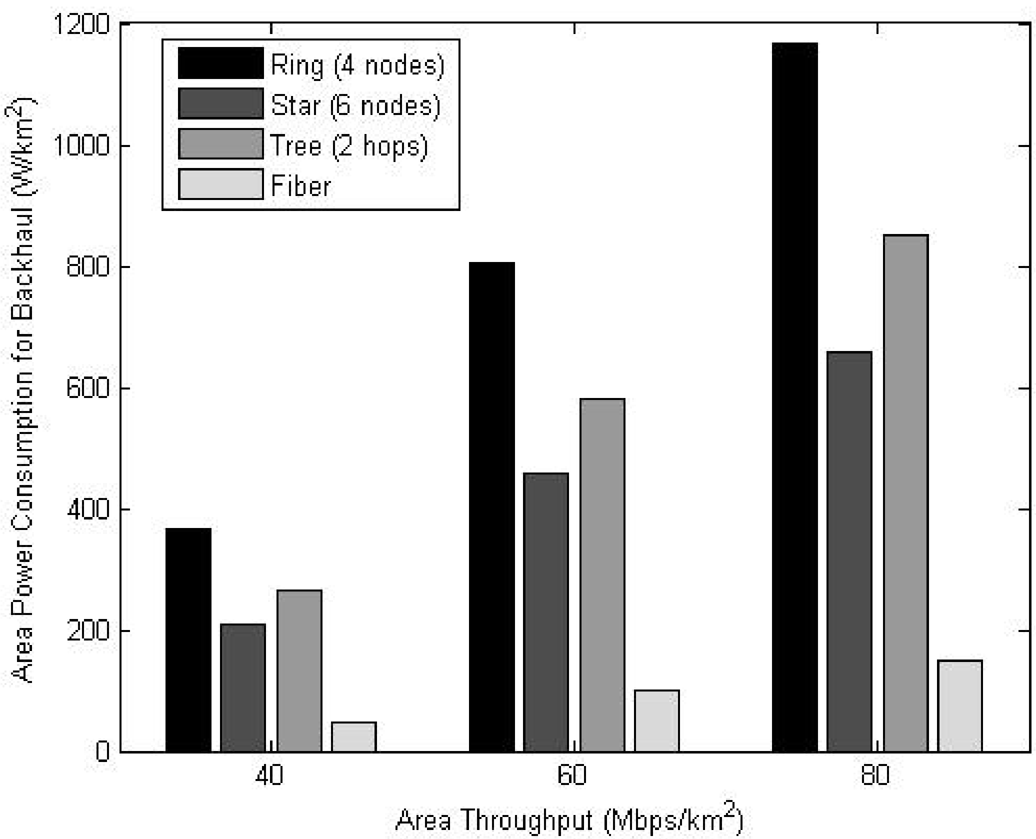
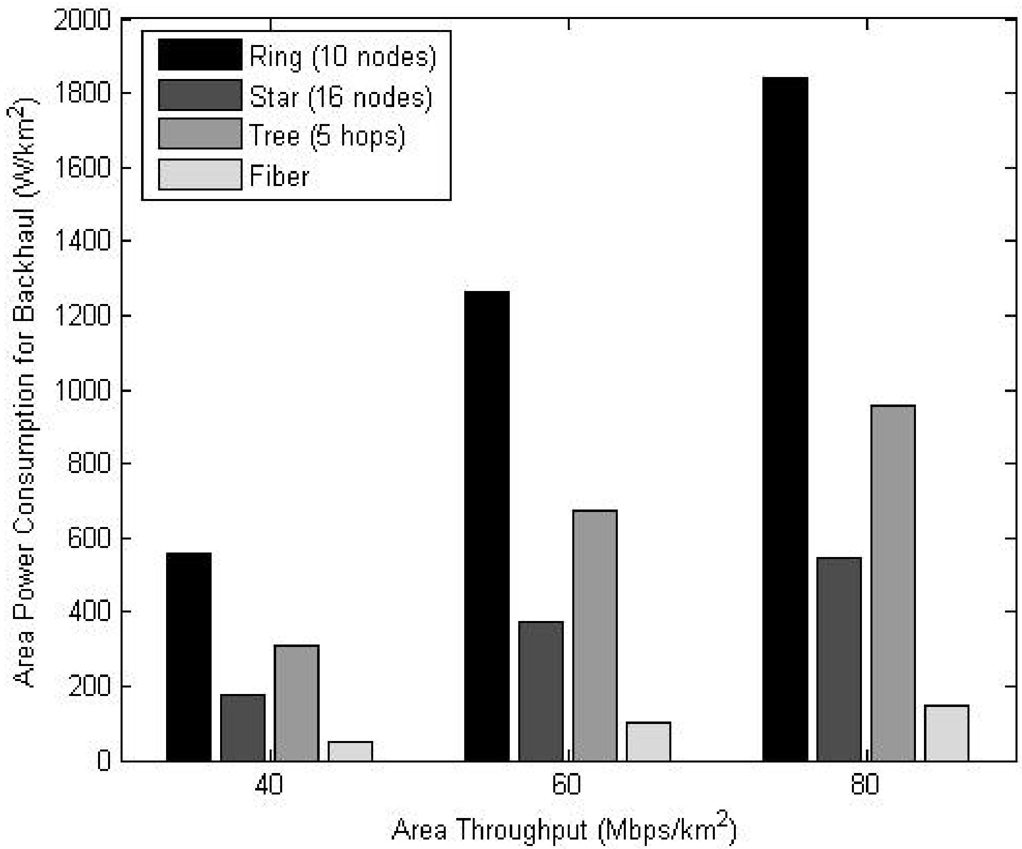
Backhaul power consumption: MW vs. Fiber

- Macro + Pico case
- Two scenarios: small size (left) and large size microwave topologies (right)





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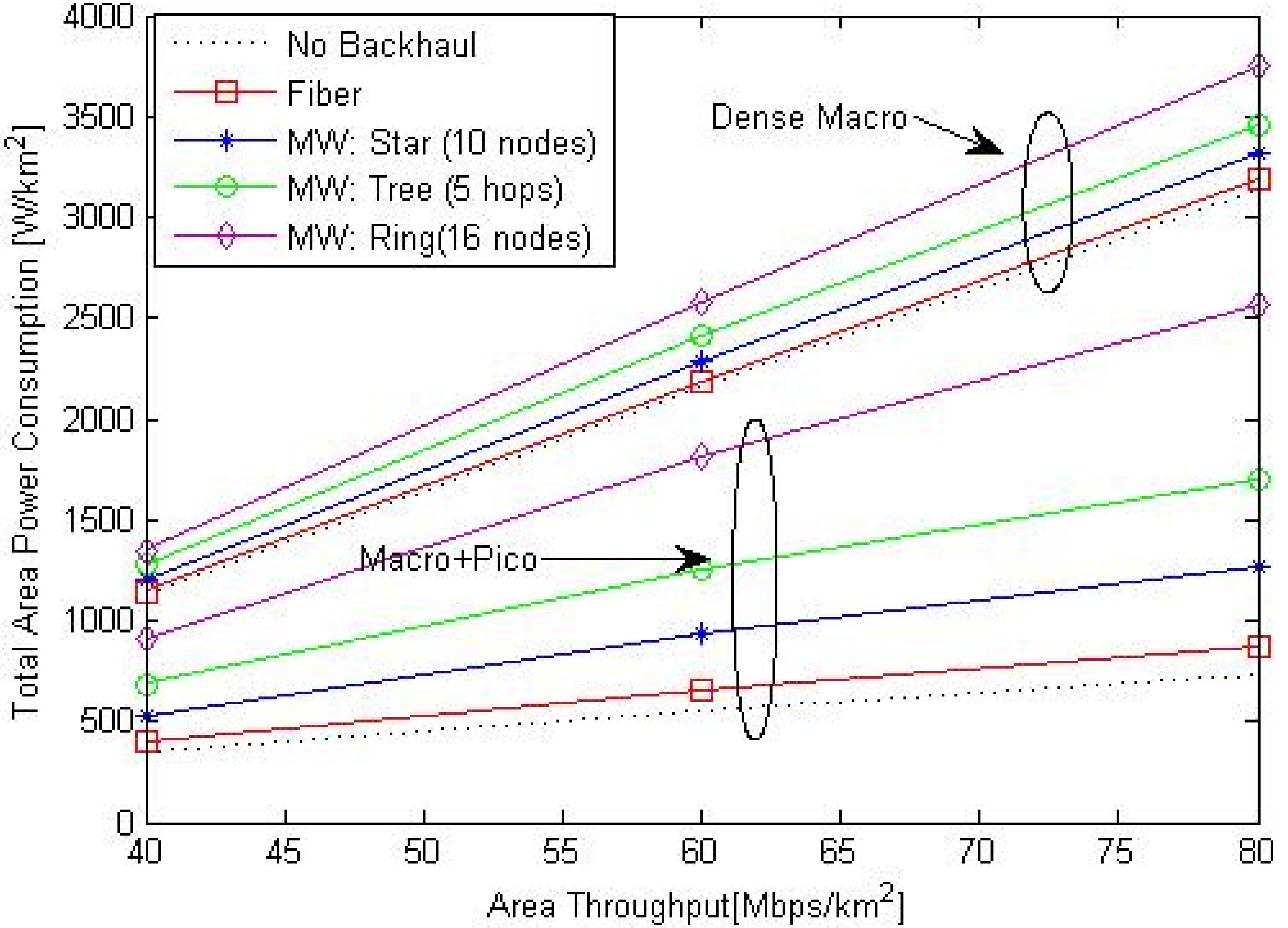
Backhaul impact on total network power consumption: outdoor case

- Three scenarios: no backhaul, MW backhaul and fiber backhaul



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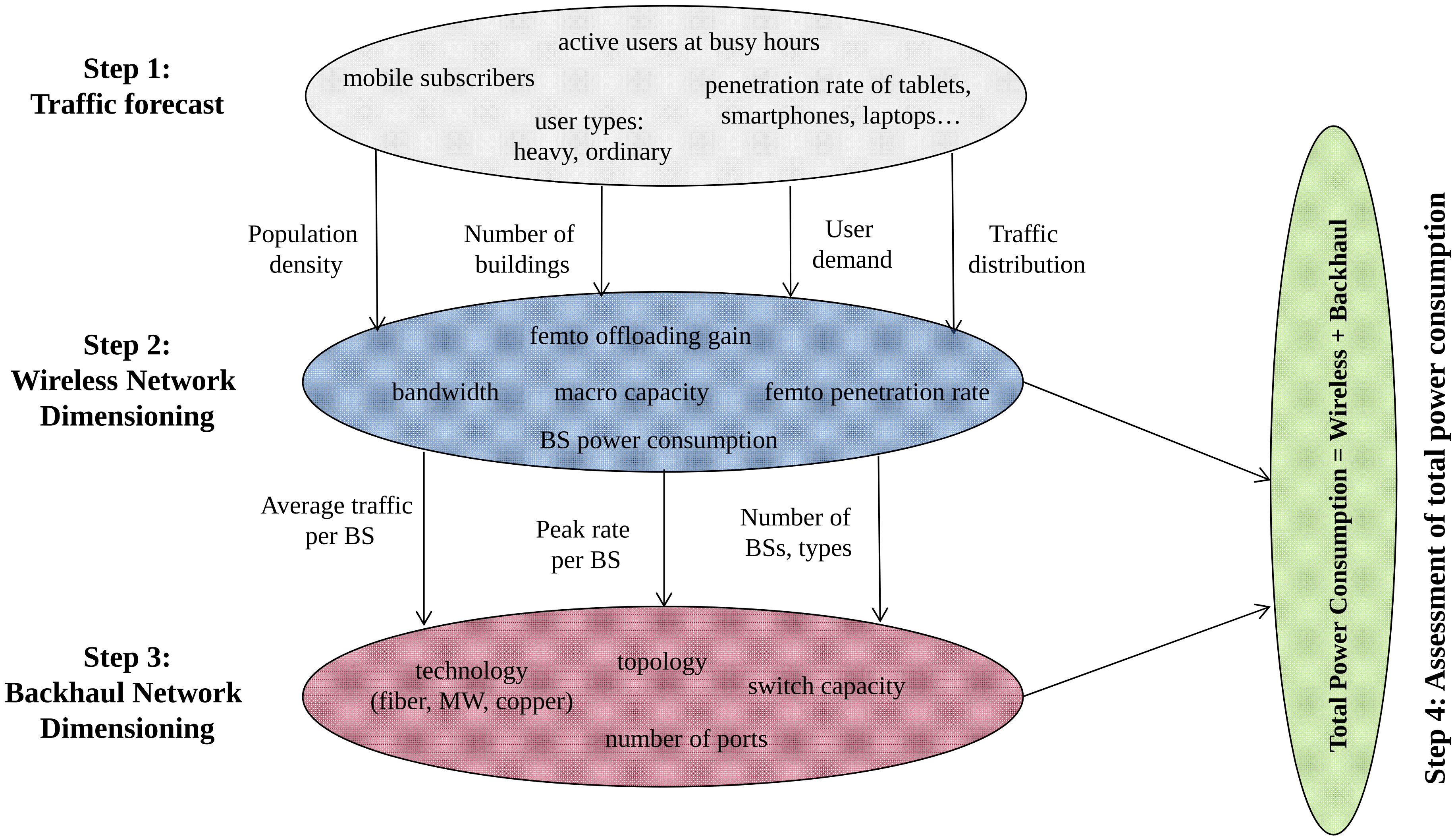
Case study: HetNet indoor deployment



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HetNet indoor deployment parameters

- Area: 10 x 10 km^2 with 300.000 users
- 100,000 apartments and 10,000 buildings
- User density: ρ = 3000 user/km^2 i.e., average EU city [Earth project]
- Femto penetration rate (η) ∈ (0.1, 0.6)
- Indoor users covered by femto BS, outdoor users by macro BS

Year	h	s_{pc}/r_{pc}^{heavy}	$s_{tablet}/r_{tablet}^{heavy}$	$s_{s.phone}/r_{s.phone}^{heavy}$	$R_{max} = max_t(R(t))$
2010	10	0.1 / 56.25	0.03 / 28.1	0.3 / 7	2.6
2015	20	0.2 / 900	0.05 / 450	0.5 / 112.5	82.8
2020	30	0.3 / 2700	0.1 / 1350	0.6 / 337	474.3

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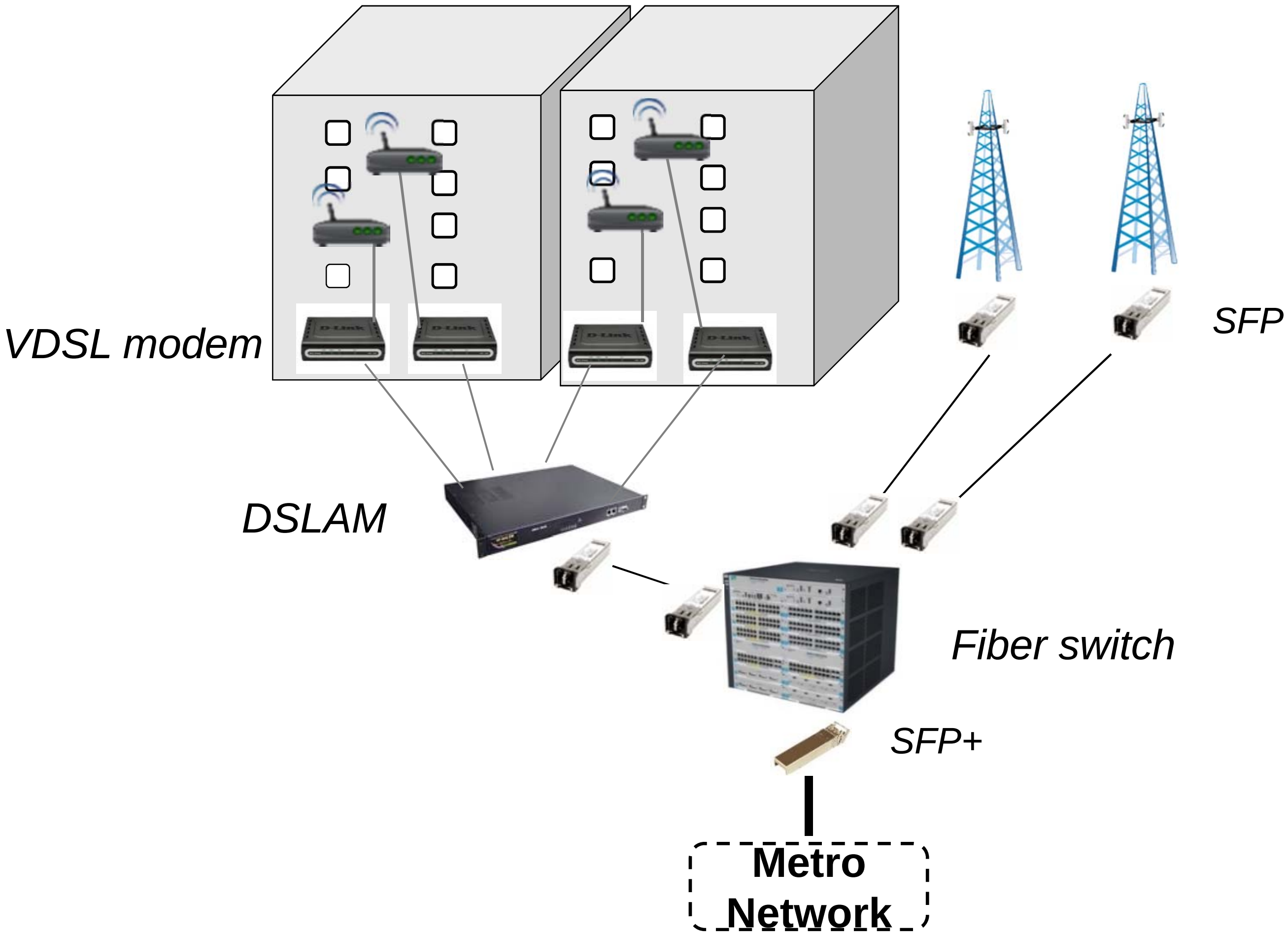
Indoor deployment: backhaul architectures

- Femto BS will not drive the deployment of a completely independent backhaul infrastructure
- Rely on existing residential broadband access technologies (backhaul and user data share the access bandwidth)
- Considered BH options:
  - FTTN + VDSL
  - FTTB with PtP optical links
  - FTTH with passive optical networks (PON)
  - Microwave only

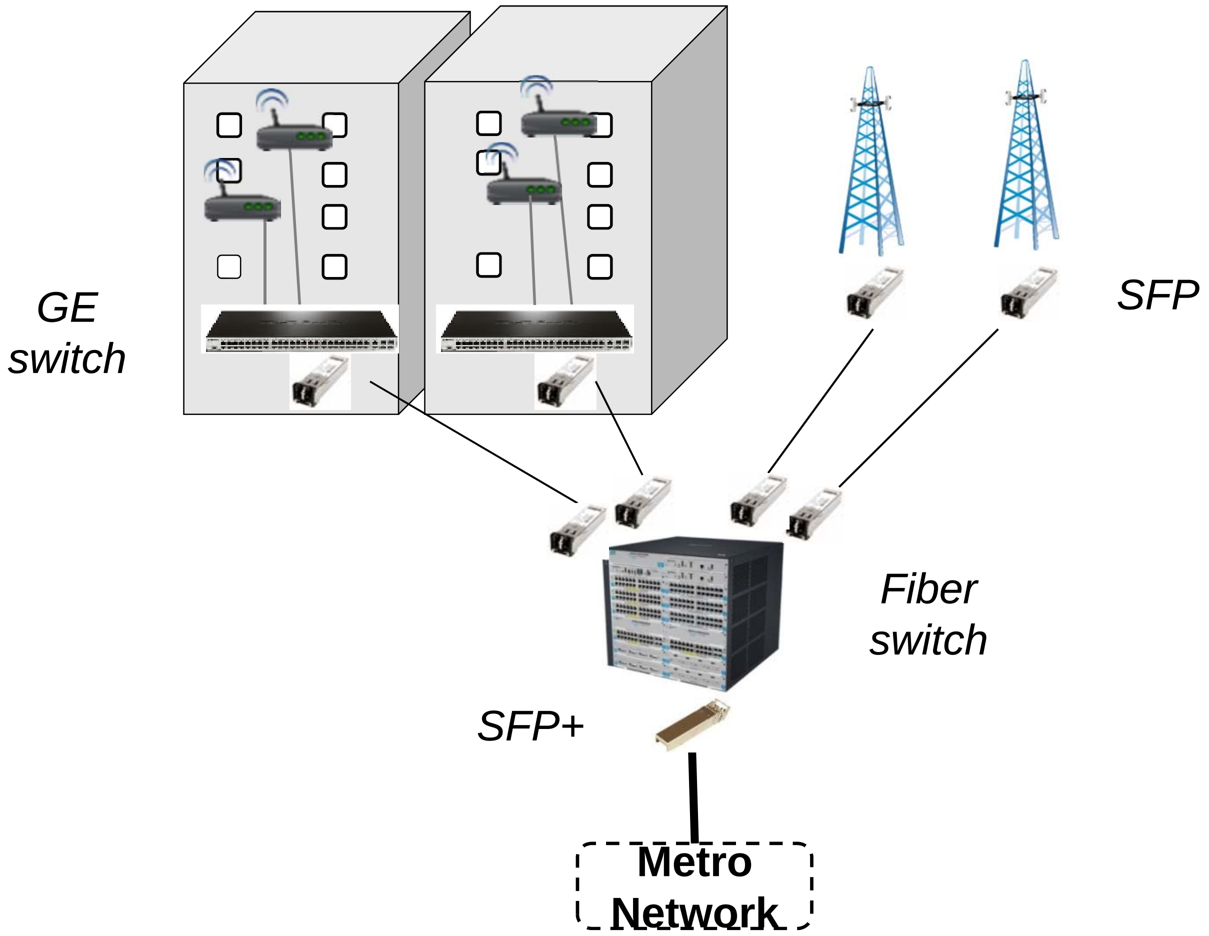
$$\mathcal{P} = \sum_{i=1}^{m} N_i P_i + P_{bh},$$

BH with FTTN + VDSL



$$P_{MBH}^{FTTN} = N_{femto}P_{modem}+N_{DSLAM}(P_{DSLAM}+2P_{SFP})+N_s^F P_s^F+2N_{macro}P_{SFP}+N_{ul}P_{SFP+}$$

BH with FTTB with PtP optical links



$$P_{MBH}^{FTTB} = N_b(P_{GES} + 2P_{SFP}) + 2N_{macro}P_{SFP} + N_s^F P_s^F + N_{ul}P_{SFP+}$$

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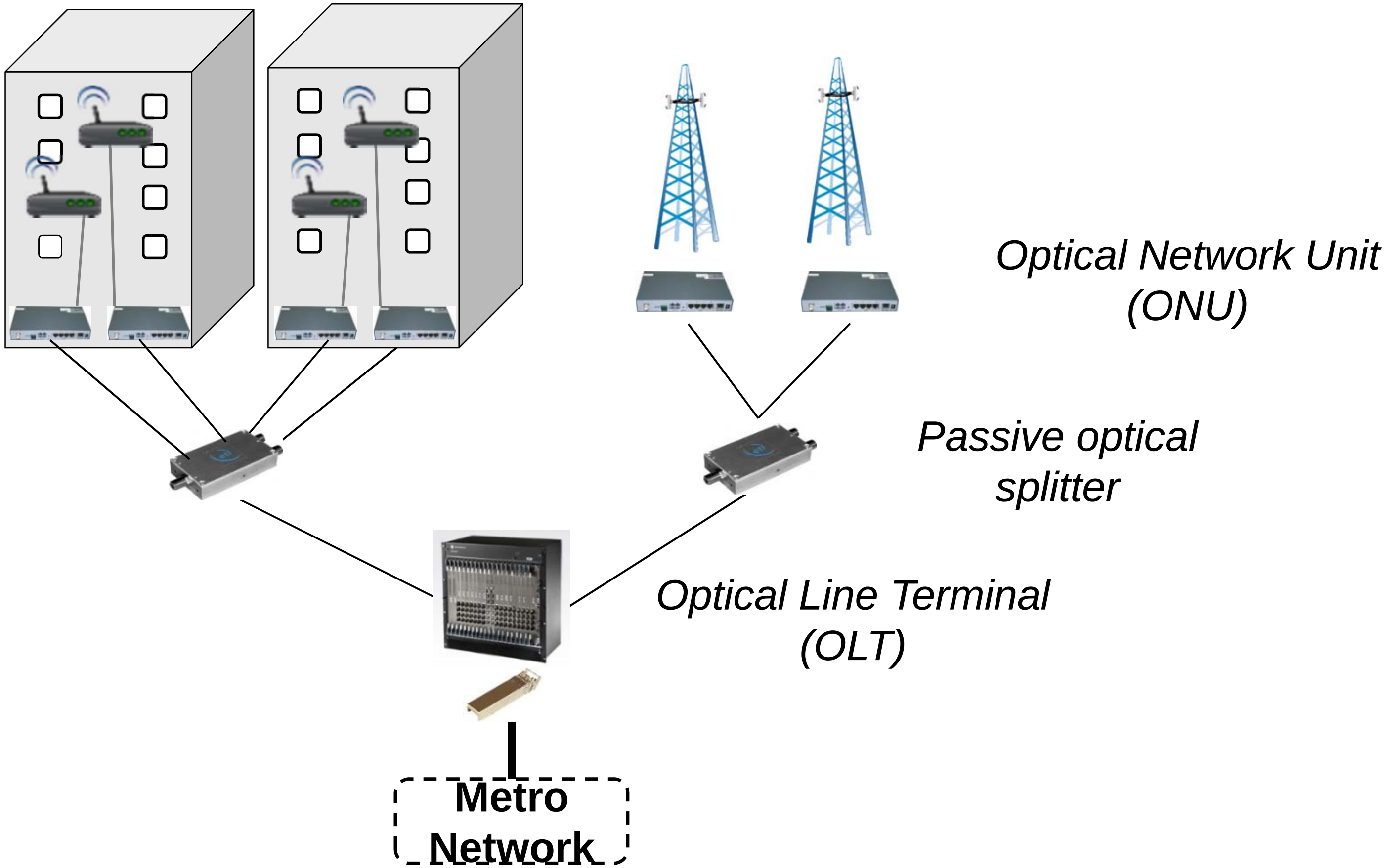
BH with FTTH using PON



$$P_{MBH}^{FTTH} = (N_{femto} + N_{macro})P_{ONU} + N_{OLT}P_{OLT} + N_{ul}P_{SFP+}$$

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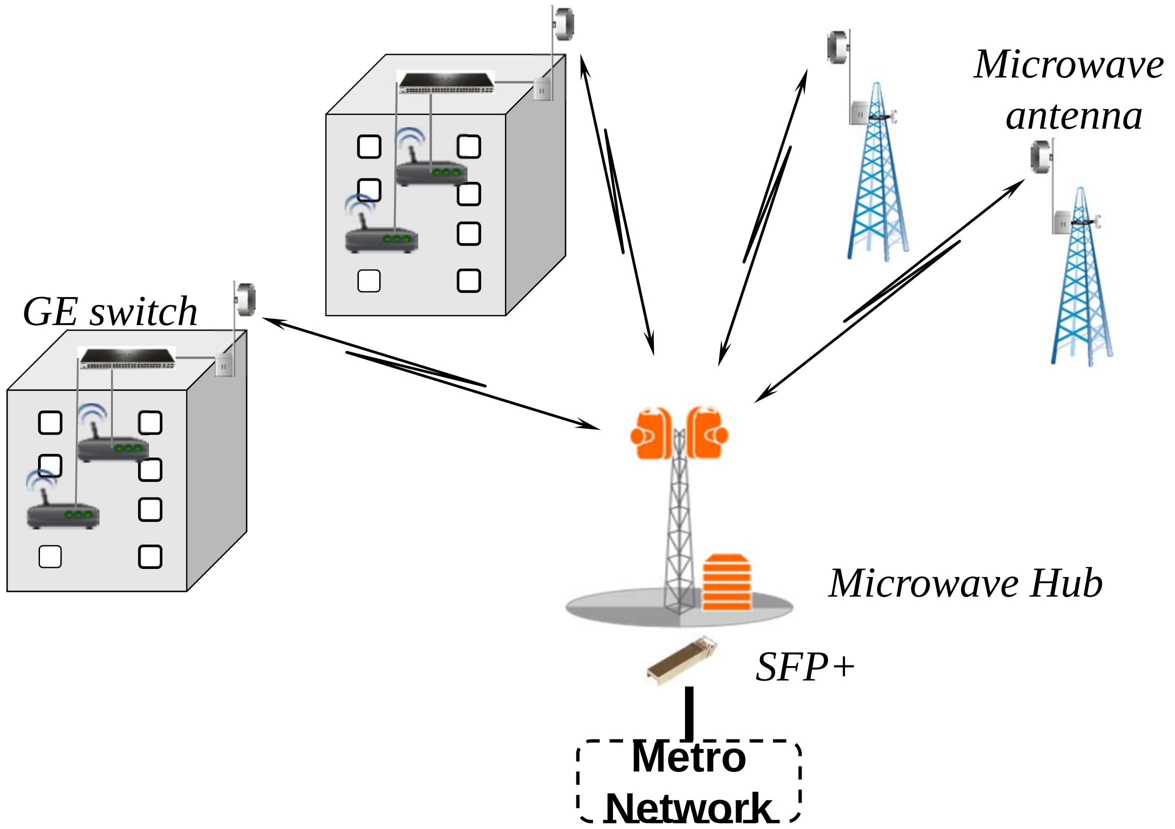
BH with microwave only



$$P^{MW}_{MBH} = \sum_{j=1}^{N_b+N_{macro}+N_{hub}} P^{MW}_j + N_{GES}P_{GES} + N_{ul}P_{SFP+}$$

$$P^{MW}_j = \begin{cases} P_{low-c} & \text{if } N^{ant}_j = 1 \\ P_{high-c} + P^{MW}_s \left\lceil \frac{C_j}{C^{MW}_{switch}} \right\rceil & \text{otherwise} \end{cases}$$

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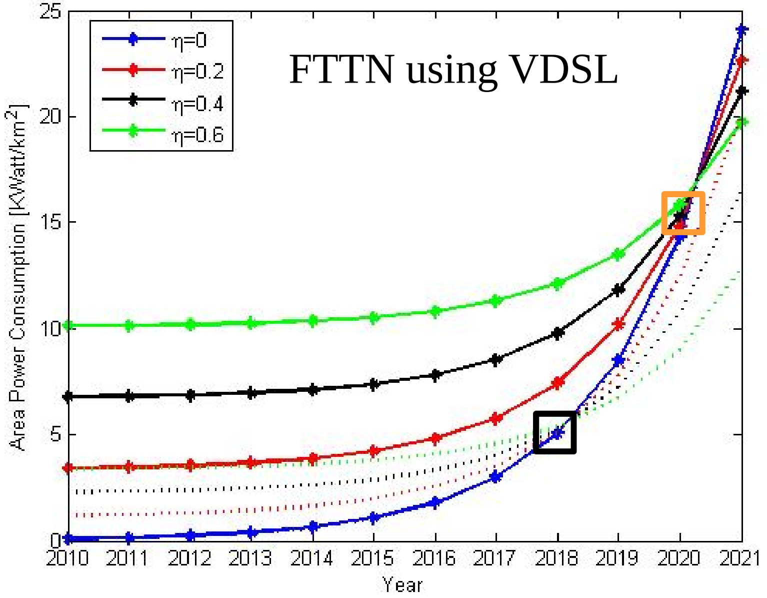
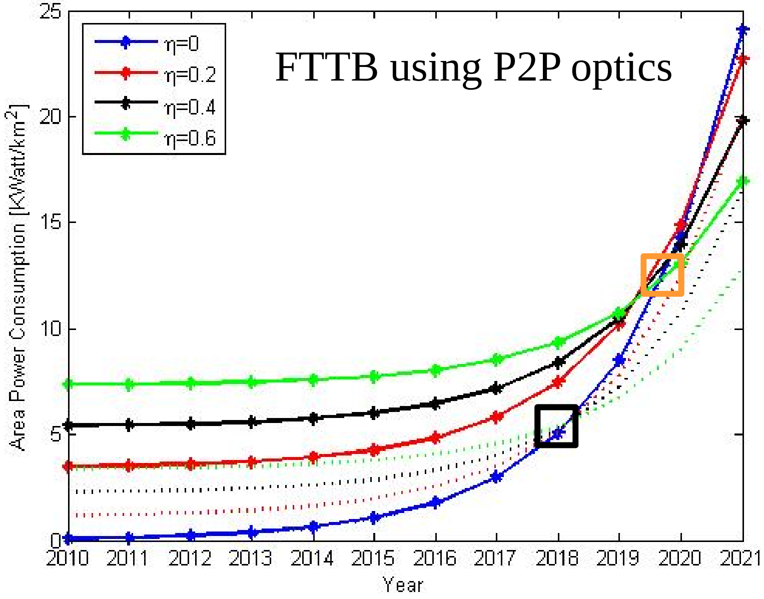
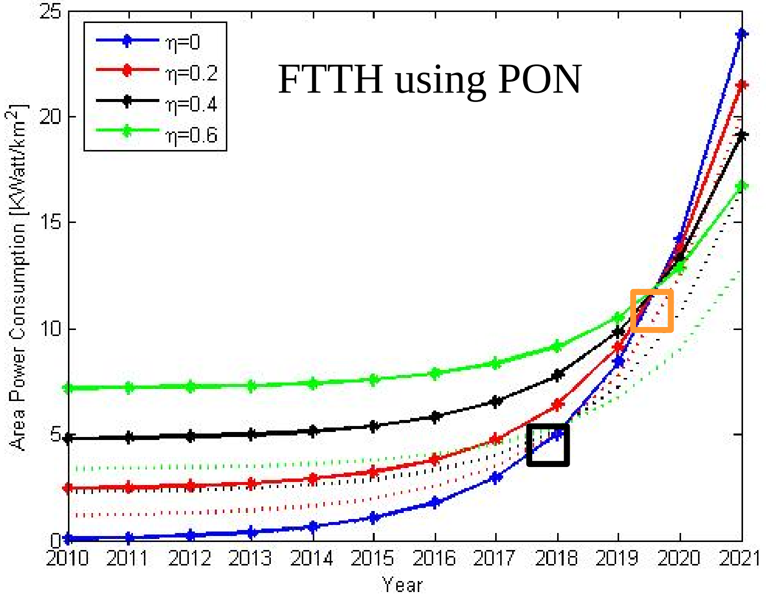
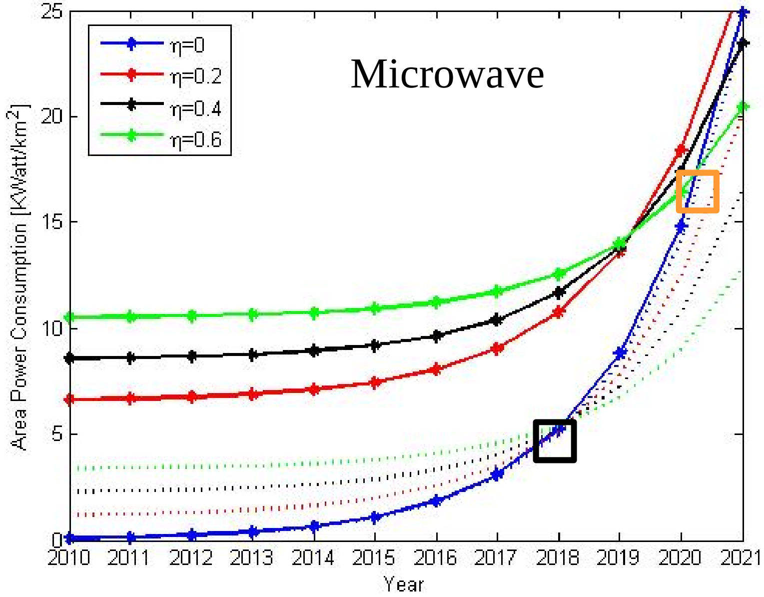
Indoor case: total power consumption









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Conclusions

- Presented two case studies assessing the impact of BH in HetNet deployments
- Power consumption of BH is important part of the total network power consumption
- It needs to be carefully included in any deployment strategy with objective of minimizing total network power consumption
- From a pure power consumption perspective a fiber based solution outperforms all the other options, but other factors of TCO shall also be included in future studies

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References

- F.S. Farias, P. Monti, A. Västberg, M. Nilson, J. C. W. A. Costa, L. Wosinska, "Green Backhauling for Heterogeneous Mobile Access Networks: What Are the Challenges?," in Proc. of IEEE Conference on Information, Communications and Signal Processing (ICICS), December 10-13, Tainan, Taiwan, 2013

- P. Monti, S. Tombaz, L. Wosinska, J. Zander, "Mobile Backhaul in Heterogeneous Network Deployments: Technology Options and Power Consumption", in Proc. of IEEE International Conference on Transparent Optical Networks (ICTON), July 2-6, Warwick, UK, 2012

- S. Tombaz, P. Monti, K. Wang, A. Västberg, M. Forzati, J. Zander, "Impact of Backhauling Power Consumption on the Deployment of Heterogeneous Mobile Networks," in Proc. of IEEE Global Communication Conference (GLOBECOM), December 5-9, Houston, TX, USA, 2011.

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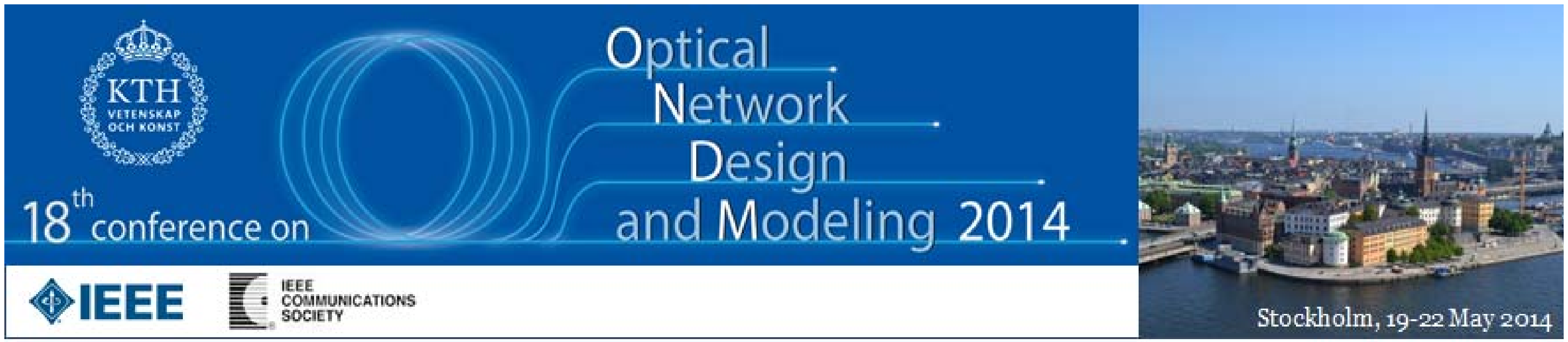
Submission Deadline January 10



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