Architekturen und Wettbewerbsmodelle bei Glasfasernetzen

Ergebnisse einer Studie für Vodafone plc

Präsentation
auf der 12. Sitzung
des NGA-Forums

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Bonn, 4. Mai 2011

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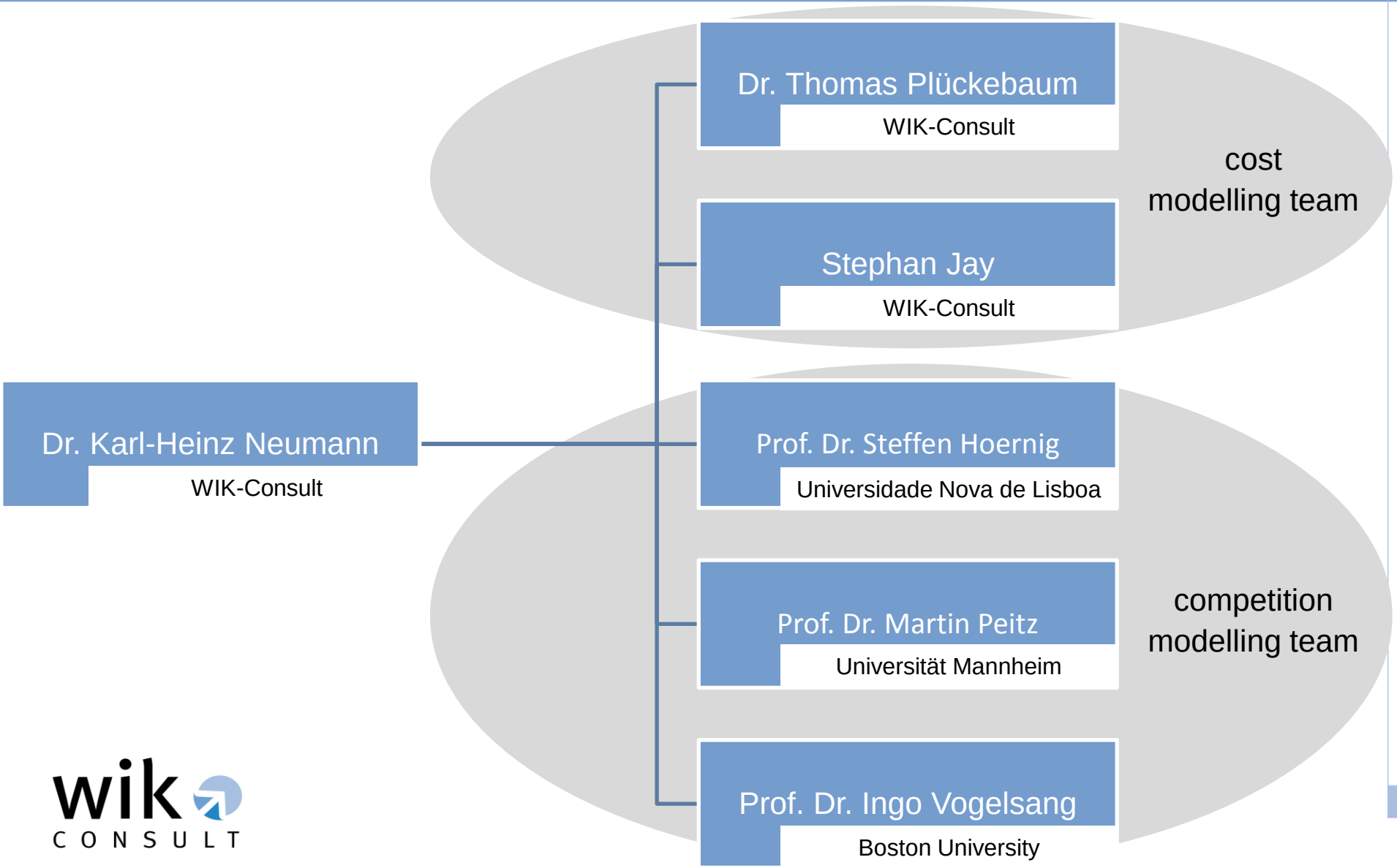
Project team



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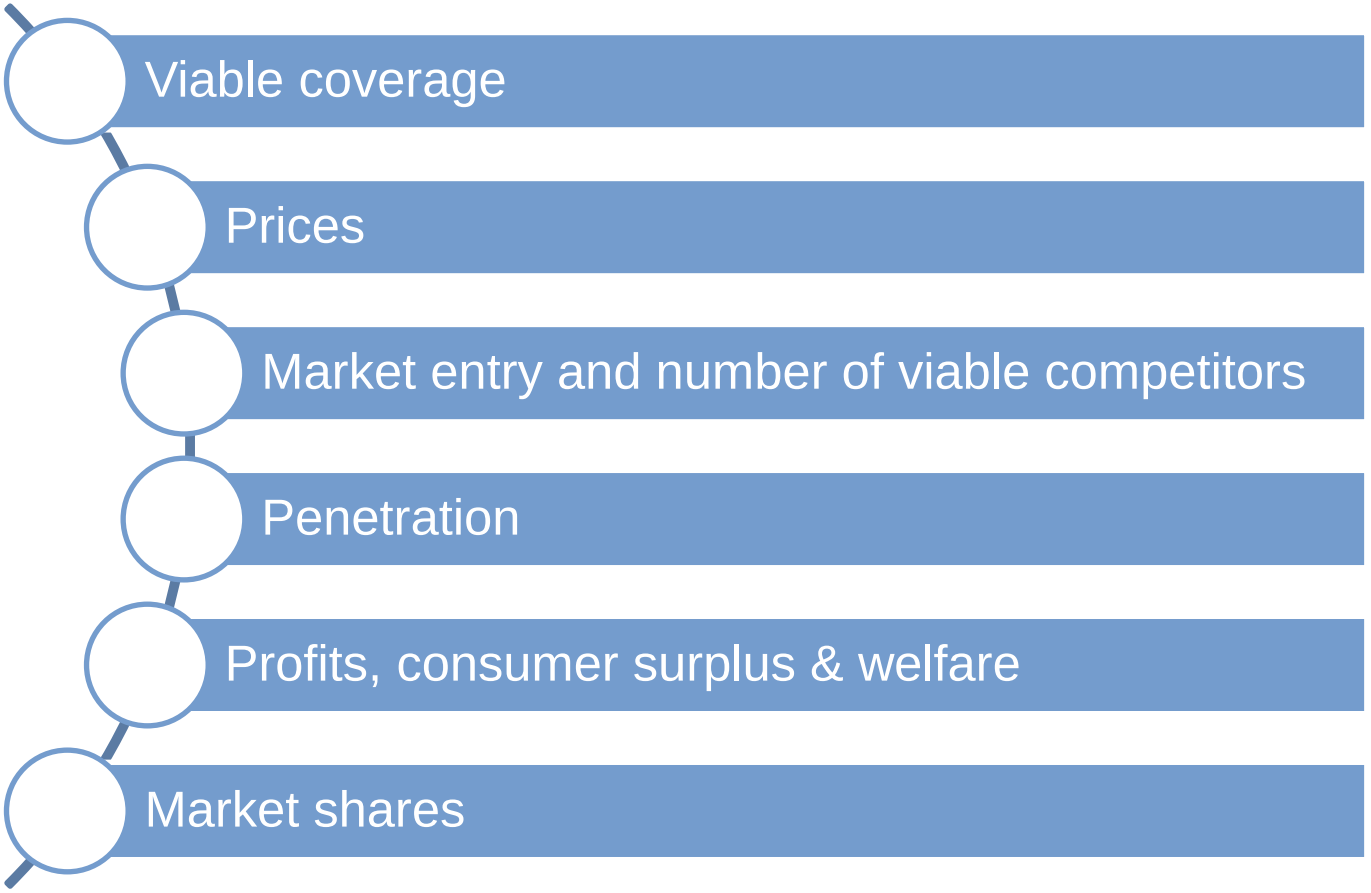
Goal: Examine cost differences and competitive outcomes of different FTTH technologies and determine impact on…



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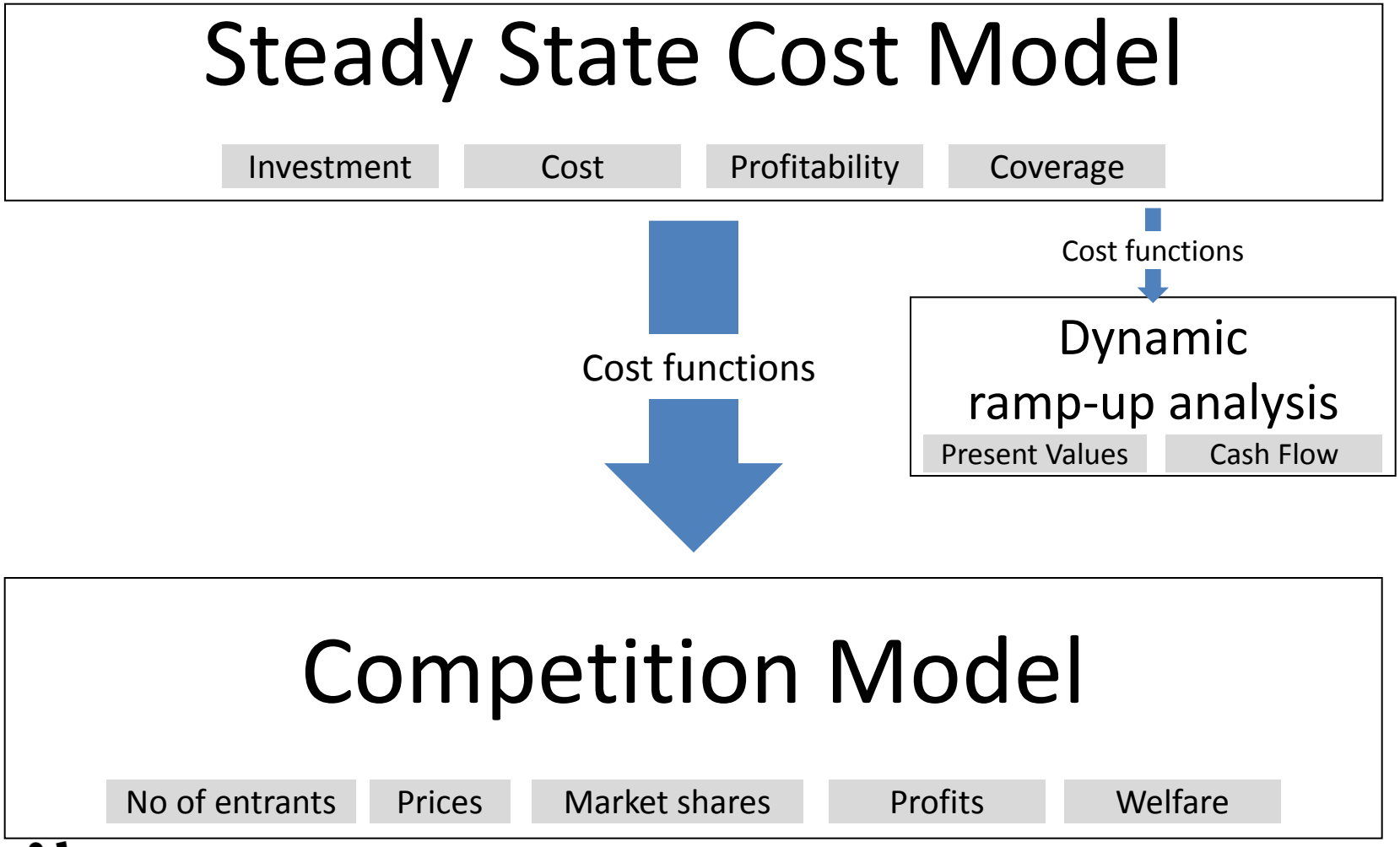
Two cost models and a 4-stage competition model developed to model cost and competition in "Euroland"



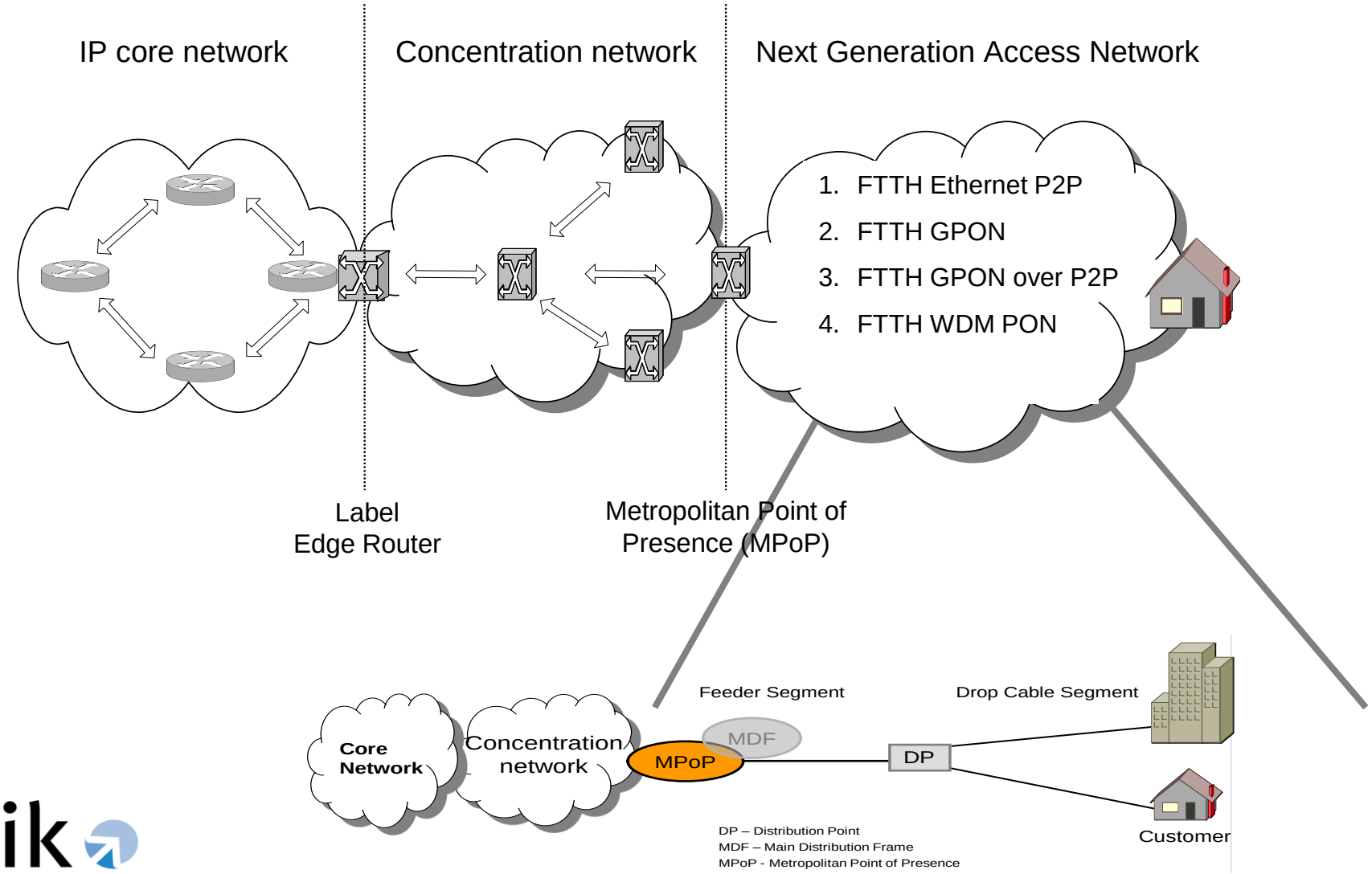
The country considered is „Euroland“

- WIK’s parameter source: Detailed countrywide geo-modelling of several European countries
- Key parameters defined and scaled to reflect a ~20mn household country (~40mn inhabitants)
  - Household density
  - Trench length per household
  - Civil works cost
  - Construction form (ducted, aerial, …)
  - Cost differentiated per cluster
- **The competition model runs over aggregate cost functions of clusters 1-4 (~8.6mn lines)**
- Addressable market = 70%* (~6mn)

Geotype	Cluster ID	customers per km²	average trench length per customer (m)	number of MPoPs
Dense urban	**1**	4000	2,4	69
Urban	**2**	1600	5,4	168
Less Urban	**3**	800	7,8	252
Dense Suburban	**4**	470	10,2	280
Suburban	**5**	280	13,1	303
Less Suburban	**6**	150	17,4	417
Dense Rural	**7**	60	28,6	1.421
Rural	**8**	< 60	55,1	2.488
				5.398

*Mobile-only, cable, non-user

We analyse four different NGA architectures



4 access technologies with 5 wholesale scenarios considered

Suitable for Unbundling

Incumbent technology	Competitor (Entrant)
Ethernet P2P	Fibre LLU at MPoP
GPON over P2P	Fibre LLU at MPoP
WDM PON	WDM unbundling at Core Nodes

Bitstream-only

Incumbent technology	Competitor (Entrant)
GPON	Bitstream Access at Core Nodes
	Bitstream Access at MPoP

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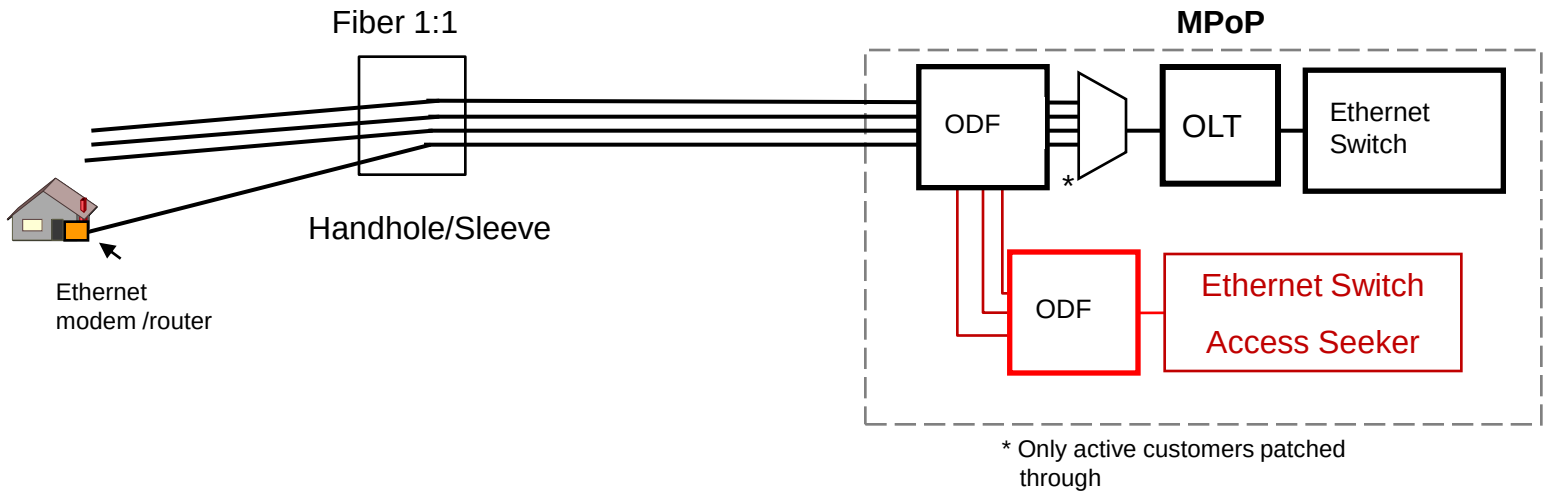
GPON over Point-to-Point fibre, Combines advantages of P2P with optimized GPON components



Incumbent cost (relevant for LLU price)

- CPE
- Access Network incl. inhouse cabling
- ODF + Patch cabling + floorspace
- Splitter + OLT + floorspace + Energy
- Ethernet Switch + floorspace + Energy
- Network sided Ethernet port (1 per MPoP)

- Concentration Network
- Core Network

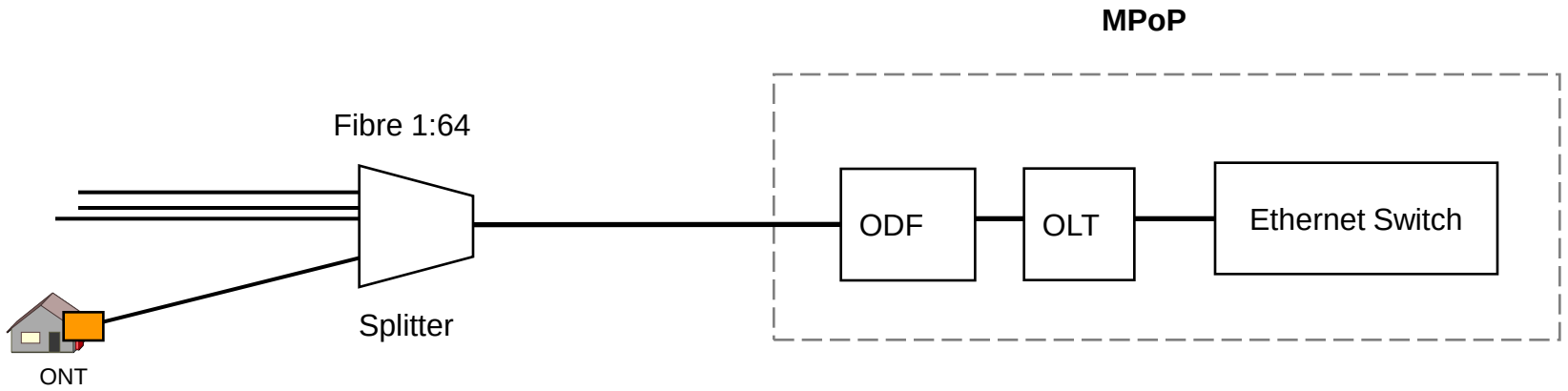
Competitor Cost**

- CPE
- LLU charge
- Competitor‘s ODF & Patch cabling + floorspace
- Ethernet Switch + floorspace + energy
- Network sided Ethernet port (1 per MPoP)

- Concentration Network
- Core Network

** Assumption: Unbundler operates Ethernet P2P network

GPON bitstream access at MPoP level



Incumbent cost (relevant for bitstream price)

- CPE
- Access Network incl. inhouse cabling
- ODF + Patch cabling + floorspace
- OLT + floorspace + energy
- Ethernet Switch* + floorspace + energy
- Network sided Ethernet port (1 per MPoP)*

- Concentration Network
- Core Network

Competitor Cost

- CPE
- Bitstream wholesale charge
- Network sided Ethernet port (1 per MPoP)*

- Concentration Network
- Core Network

*Network sided port of Ethernet Switch is not part of bitstream access monthly charge per subscriber.

The total cost of P2P is only ~10% higher than GPON

Cost ranking

1. GPON
2. GPON over P2P
3. WDM PON
4. P2P

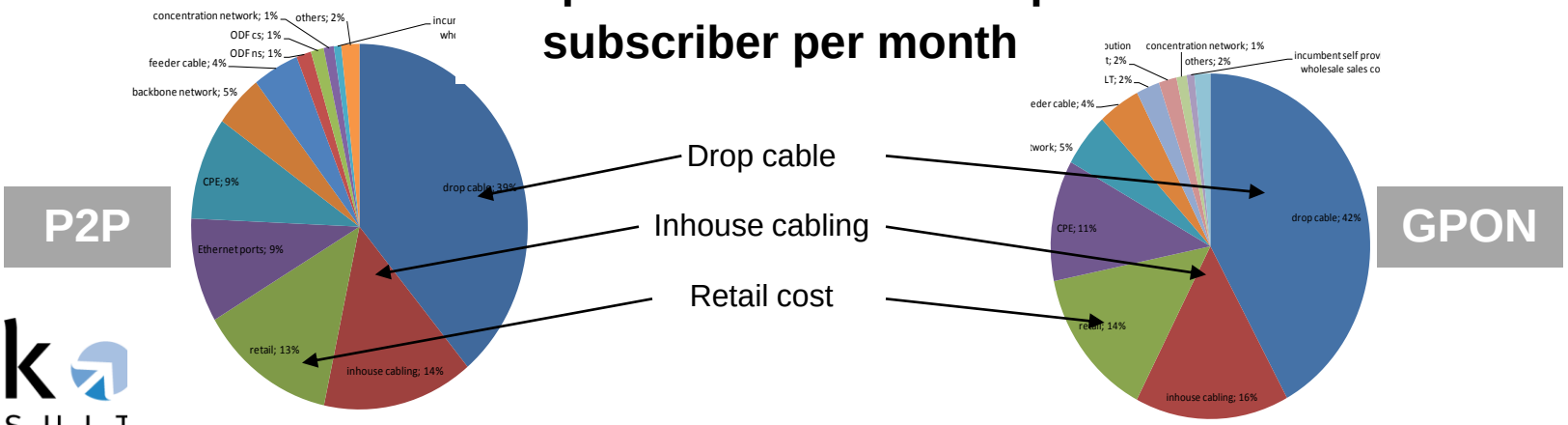
~1% cost difference

~10% cost difference

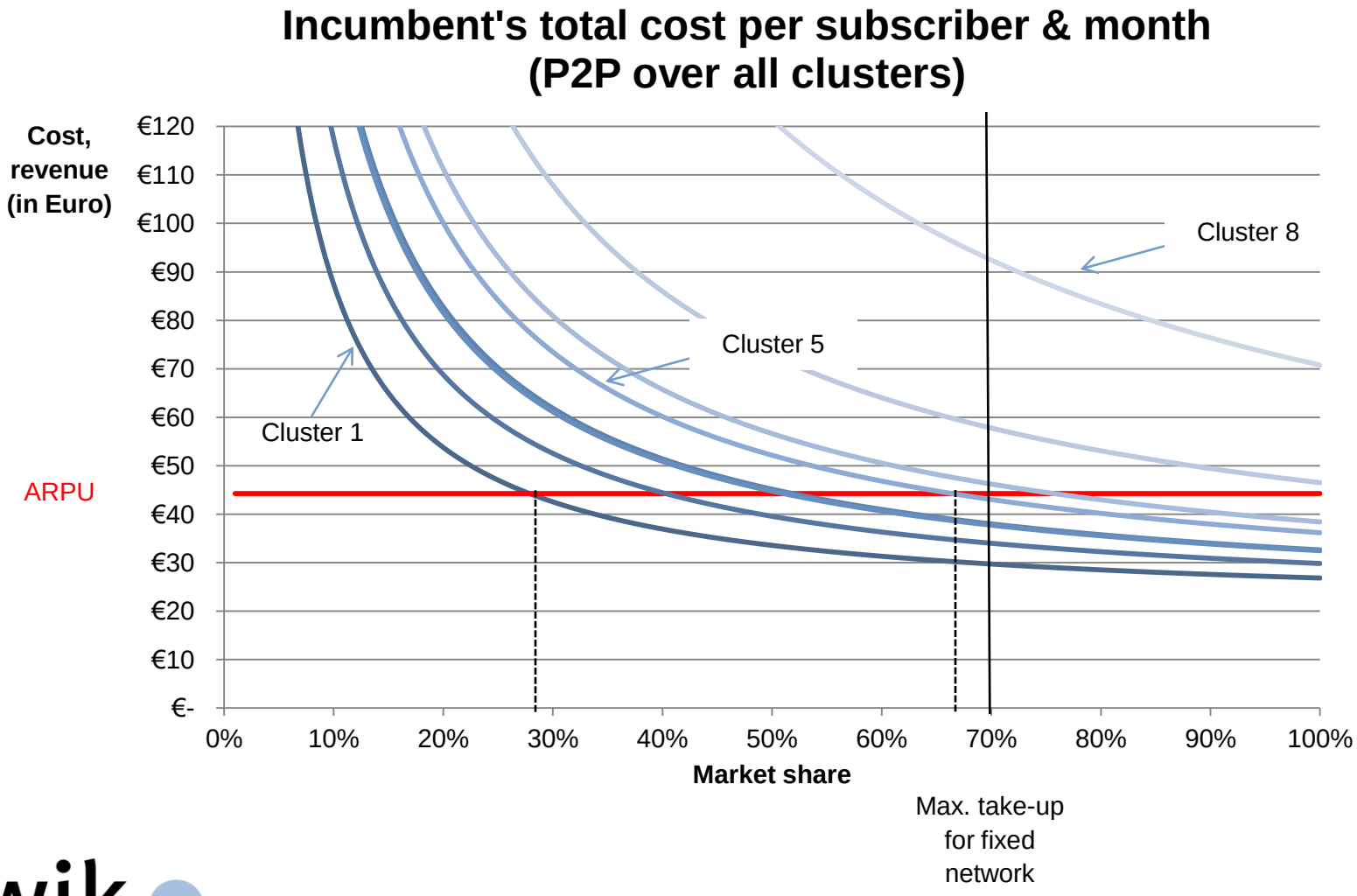
Cost comparison

- High variation for some items (energy or central office floorspace)… that make up a few % of total monthly cost
- No variation for high cost share positions such as drop cable, inhouse cabling, retail cost…

Composition of total cost per subscriber per month



As the cost per customer increases with density the penetration must be higher to operate profitably



The profitable coverage is similar between architectures

- FTTH P2P and WDM PON can operate profitably in about 50% of Euroland's customers under our assumptions regarding ARPU and addressable market
- GPON over P2P and the standard GPON could reach about 64% of all customers
- Infrastructure competition generally not realistic (infrastructure replication is theoretically possible only in the densest cluster)

P2P GPON

Architecture:	P2P			Critical market shares		Critical market shares		
Geotype	**Cluster ID**	**Potential customers**	**Potential customers (cumulated in %)**	**Incumbent**	**Competitor (LLU) (Scenario 1)**	**Incumbent**	**Competitor Bitstream Core (Scenario 3a)**	**Competitor Bitstream MPoP (Scenario 3b)**
Dense urban	1	1.763.916	8,1%	29%	9%	26%	4%	6%
Urban	2	2.163.672	18,0%	41%	10%	38%	3%	5%
Less Urban	3	2.646.000	30,1%	53%	24%	48%	4%	8%
Dense Suburban	4	2.062.480	39,5%	52%	25%	47%	5%	10%
Suburban	5	2.460.360	50,7%	67%	> 100%	60%	16%	28%
Less Suburban	6	2.989.056	64,4%	76%	> 100%	69%	> 100%	> 100%
Dense Rural	7	4.331.208	84,2%	> 100%	> 100%	98%	> 100%	> 100%
Rural	8	3.448.368	100,0%	> 100%	> 100%	> 100%	> 100%	> 100%

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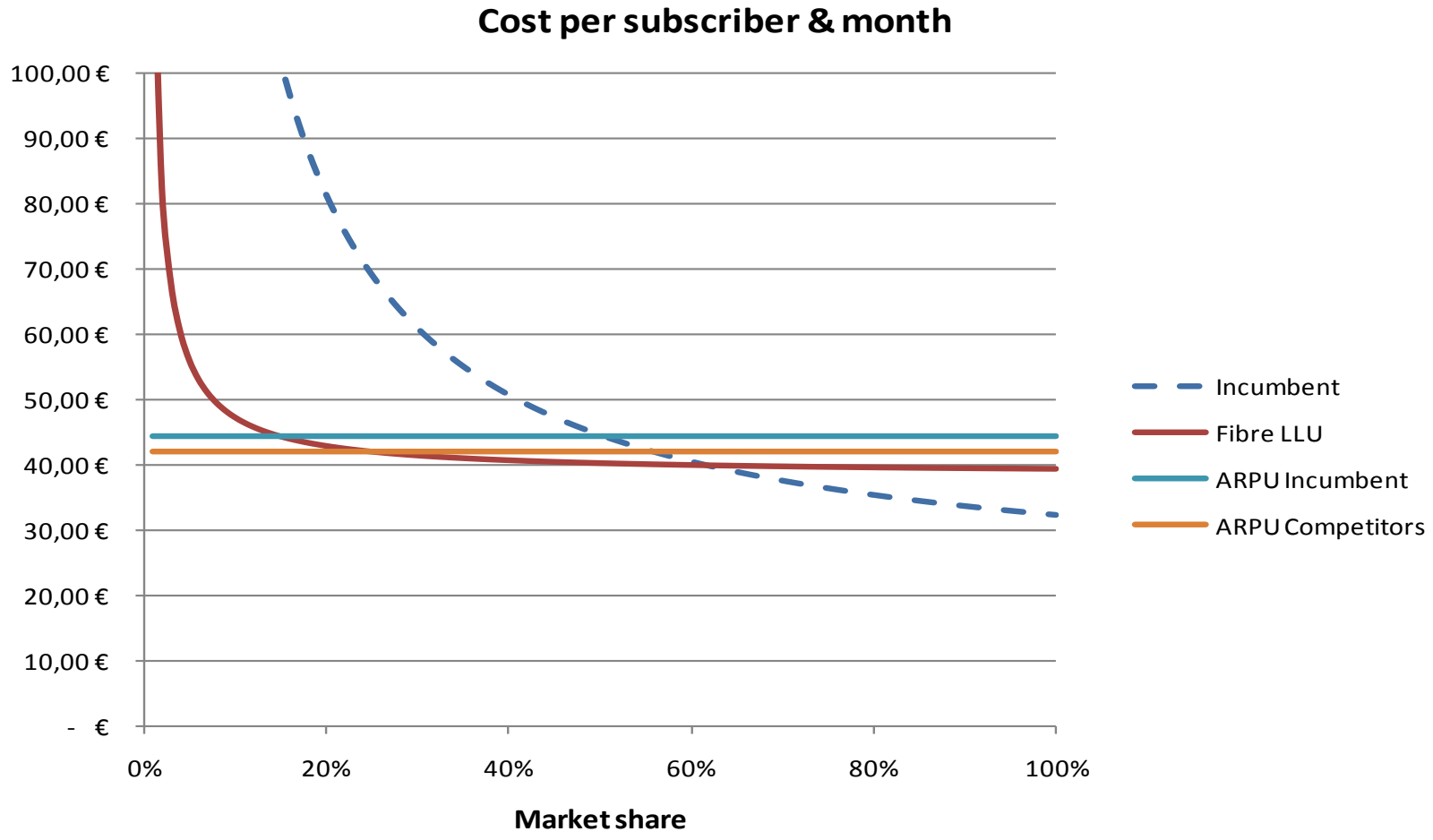
P2P Cost curves of incumbent and competitors differ significantly (Cluster 4)



Entrants can survive at low market shares but are very sensitive to small changes in price!

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Strategic competition model

- Strategic interaction of market players
  - In most cases, incumbent as investor
  - Access-based competitors and cable
- Pyramid model similar to Hotelling model used to define the customers‘ preference space
- QoS, Willingness to Pay, linear demand functions Incumbent or independent fibre investor as access network investor
- Cost functions (fixed and variable cost) for incumbent and competitors taken from cost model as input for competition model
- Applied to cost model results for Clusters 1 through 4 in aggregate
- Open Entry-Equilibrium (Nash), i.e. the equilibrium number of entrants generates a profit and any additional entrant generates a loss

Modelling competition in an FTTH oligopoly

4 stages of the game

- Stage 1: A planner decides on the scenario, consisting of the FTTH architecture and the mode of regulation (including aspects of access prices and QoS).
- Stage 2: The incumbent firm invests in FTTH infrastructure, based on the restrictions and incentives provided by stage 1. This includes a penetration level, access prices and QoS aspects.
- Stage 3: Potential entrants decide whether to enter or not. If they decide to enter they also decide on their level and type of investment and on QoS choices. Their choices and incentives are based on the decisions made in stages 1 and 2.
- Stage 4: Entrants and the incumbent compete for end-users in a differentiated FTTH oligopoly using prices as strategic variables.
- The game will be solved, as usual, from the last stage backwards to the first. So, the choice at stage 1 will be made last. It will be simply the result of any ranking that we come up with at the end of our analysis.

QoS and willingness to pay (WtP) in the basic model

	Incumbent QoS =WtP	Cable QoS = WtP	Entrant QoS	Entrant WtP
P2P unbundling	100	82	99	97
GPON over P2P unbundling	99	82	99	97
WDM PON unbundling	95	82	91	89
GPON Bitstream Core	90	82	85	83
GPON Bitstream MPoP	90	82	87.5	85.5

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Networks that can be unbundled are superior to bitstream-only GPON in terms of consumer surplus and welfare

– Ethernet P2P, GPON over P2P and WDM PON generate greater monthly consumer surplus and total welfare than GPON and bitstream access

Scenario	Model with cable				
	n-2	Consumer Surplus		Total Welfare	
		mn €	Rank	mn €	Rank
P2P unbundling	4	466.9	1	490.3	2
GPON over P2P unbundling	3	434.0	2	493.8	1
WDM PON unbundling	4	431.2	3	473.9	3
GPON Bitstream Core	4	400.5	5	445.7	4.5
GPON Bitstream MPoP	4	416.0	4	445.1	4.5

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Sensitivity to W and CS to WtP assumptions, ranking

- Rankings of basic model are confirmed by sensitivities on QoS, Willingness to Pay, incumbency advantage: unbundling scenarios always rank well above bitstream-only scenarios
- Sensitivities show that it is less clear which unbundling technology should be preferred

	P2P unbundling		GPON over P2P unbundling		GPON bitstream core		GPON bitstream MPoP		WDM PON unbundling	
	CS	W	CS	W	CS	W	CS	W	CS	W
Basic model	1	1.5	2.5	1.5	4	4.5	3	4.5	2.5	3
WDM PON with alternative costing	2	2.5	3.5	2.5	4	4.5	4	4.5	1	1
Increased incumbency advantage	2.5	1.5	1	1.5	4	4.5	5	4.5	2.5	3
Smaller spread	4.5	3	4.5	3	2	3	3	5	1	1
Increased incumbency advantage and smaller spread	3.5	3.5	3.5	1.5	2	3.5	5	5	1	1.5

Under certain assumptions WDM PON could be the best choice if the technology becomes commercially available for the access network

- We modeled a very forward looking WDM PON technology (1000 λ, high splitting factor, long distances allowing MDF dismantling = no concentration network needed)
- MDF consolidation should make WDM PON even more attractive to incumbents (this was reflected in our dynamic model, where WDM PON increases its position significantly relative to the other architectures)
- The relative performance of WDM PON is strongly influenced by the cost of its CPE
- Potential alternative scenarios
  - We have assumed that in the future steady state (~10 years) consumers ascribe a high value to ultra high speeds and differentiated retail offerings
  - If that is not the case and the Willingness to Pay advantage of P2P is not as strong, then WDM PON could maximize consumer surplus and total welfare
- However, there are still barriers to commercializing WDM PON (cost, standardization) that prevent deployment today

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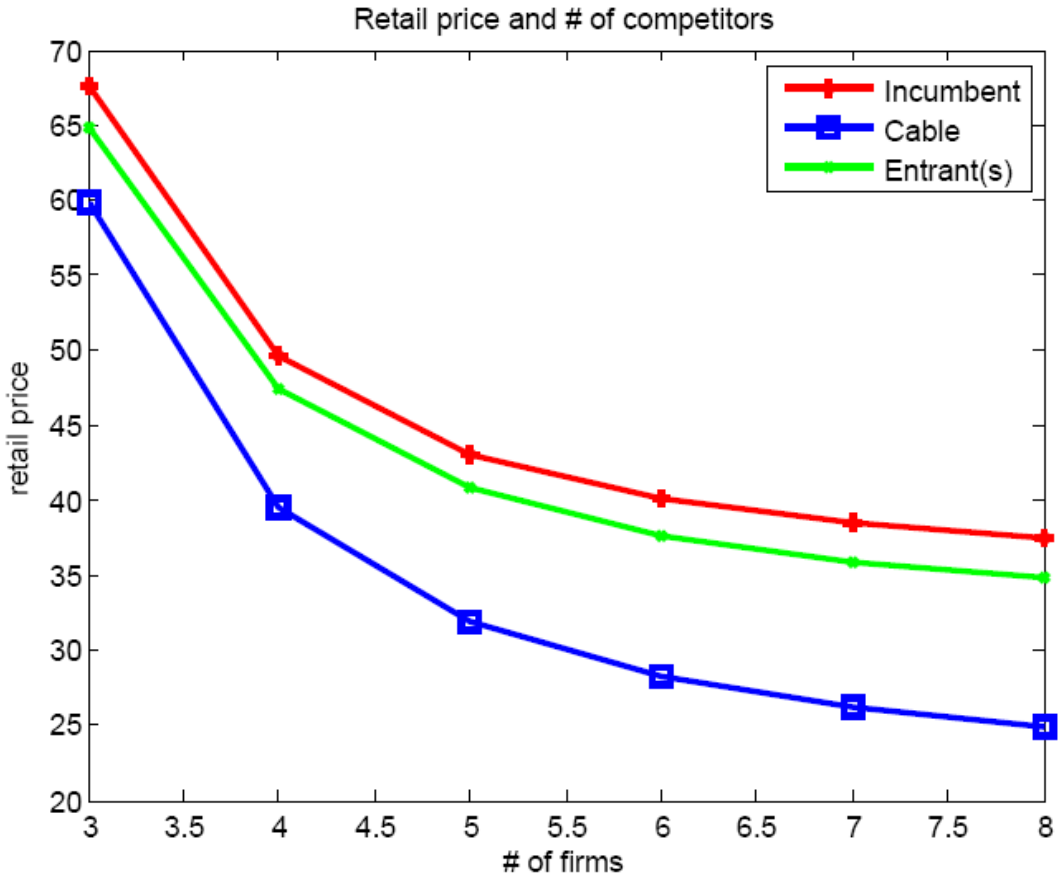
The number of firms has a huge effect on prices. It is essential to have at least 3 competitors. Scenario: GPON bitstream access at core



Retail prices are sensitive to the number of firms.
Greatest effect if the number of firms is small.
In all scenarios there are only 3 or 4 entrants in equilibrium.

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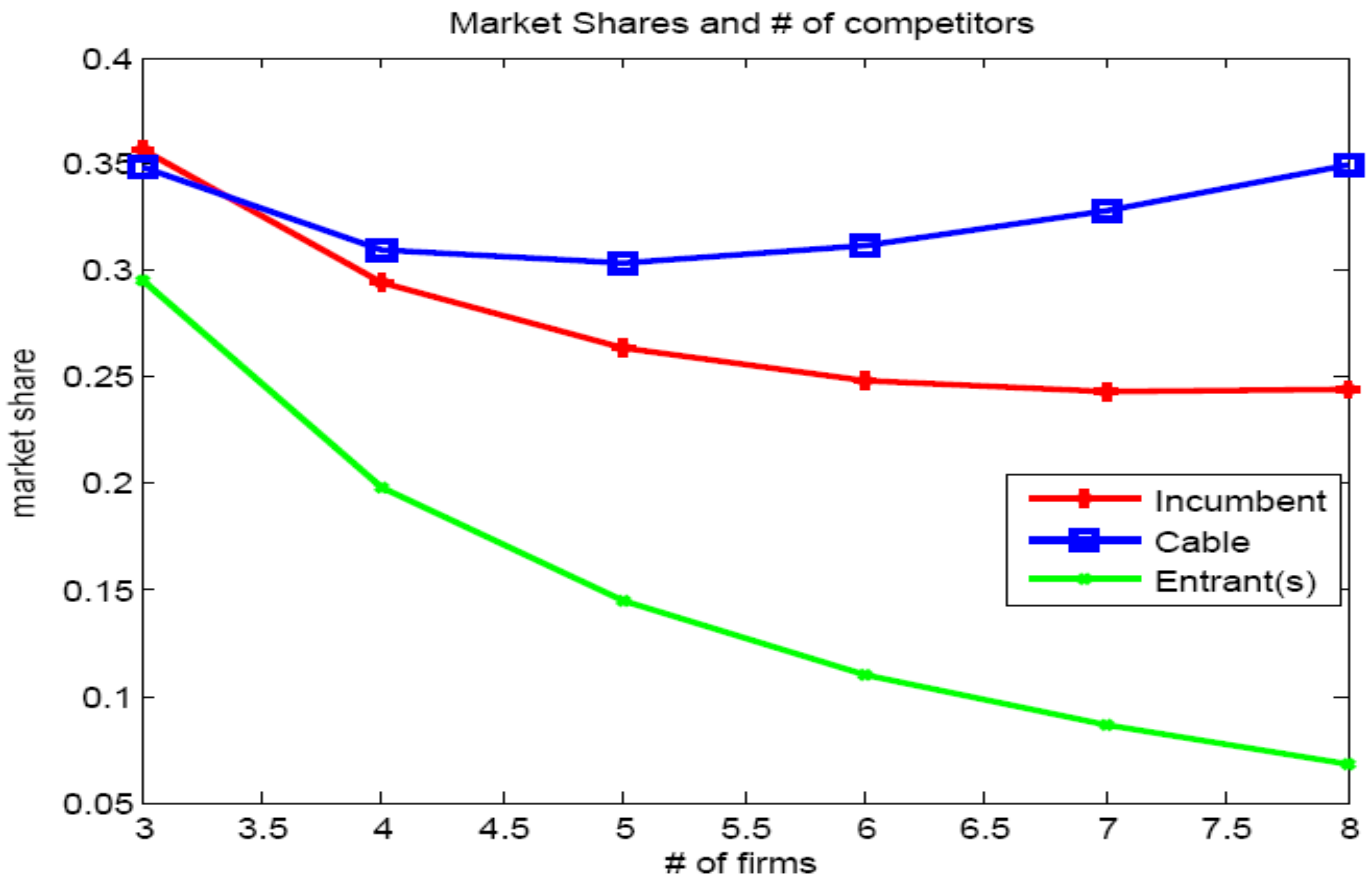
Initially all market shares decrease in number of competitors. Cable benefits. Scenario: GPON bitstream access at core



Initially all market shares decrease in number of competitors.
Cable benefits from large number of entrants.
Incumbent's market share relatively steady even with more entry.

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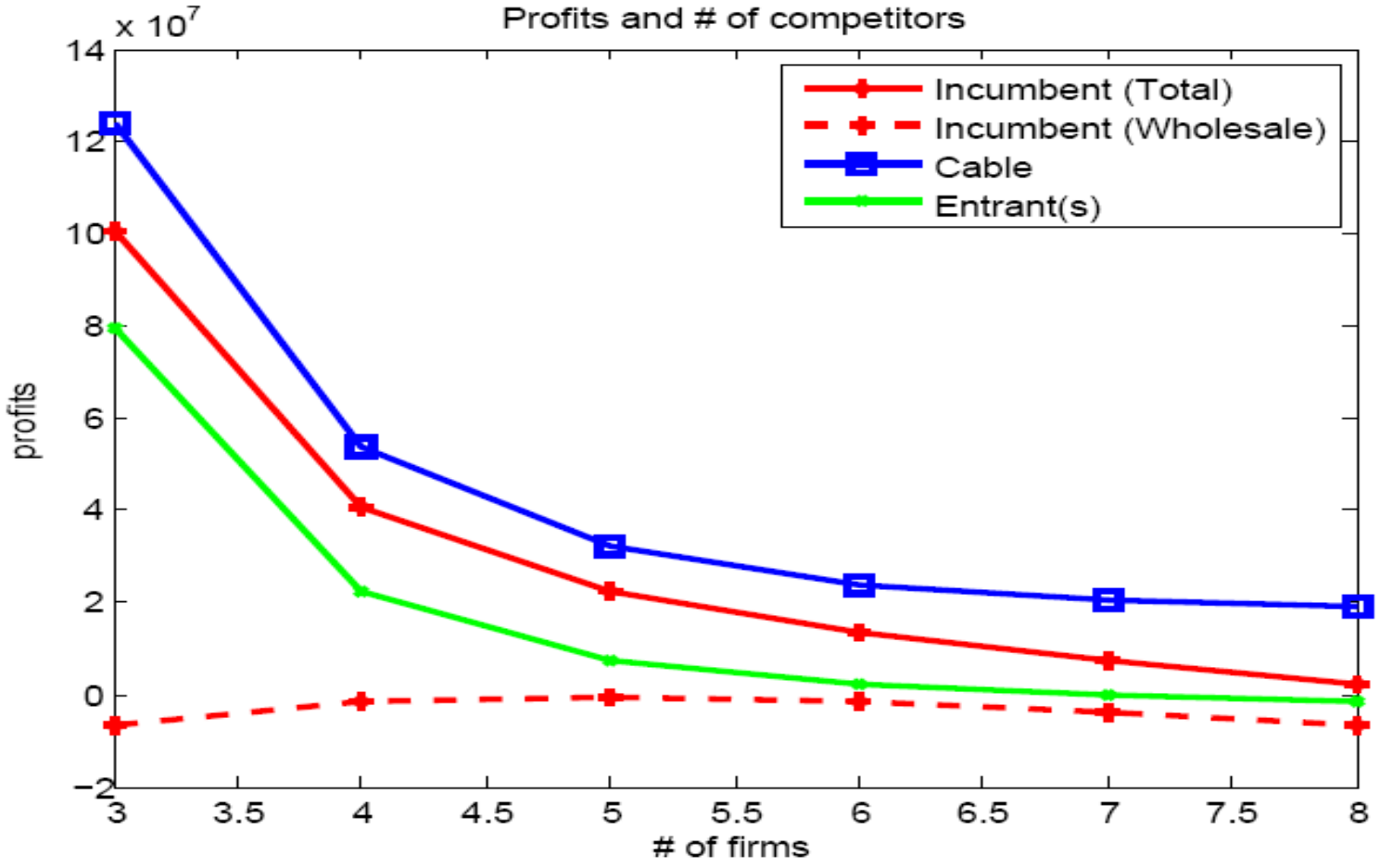
All firms' profits decrease in number of firms
Scenario: GPON bitstream access at core



Profits reflect effect of prices and market shares.
Wholesale profits = 0 for target market share of fibre (70%).
In the range of our scenario equilibria profits change substantially with entry.

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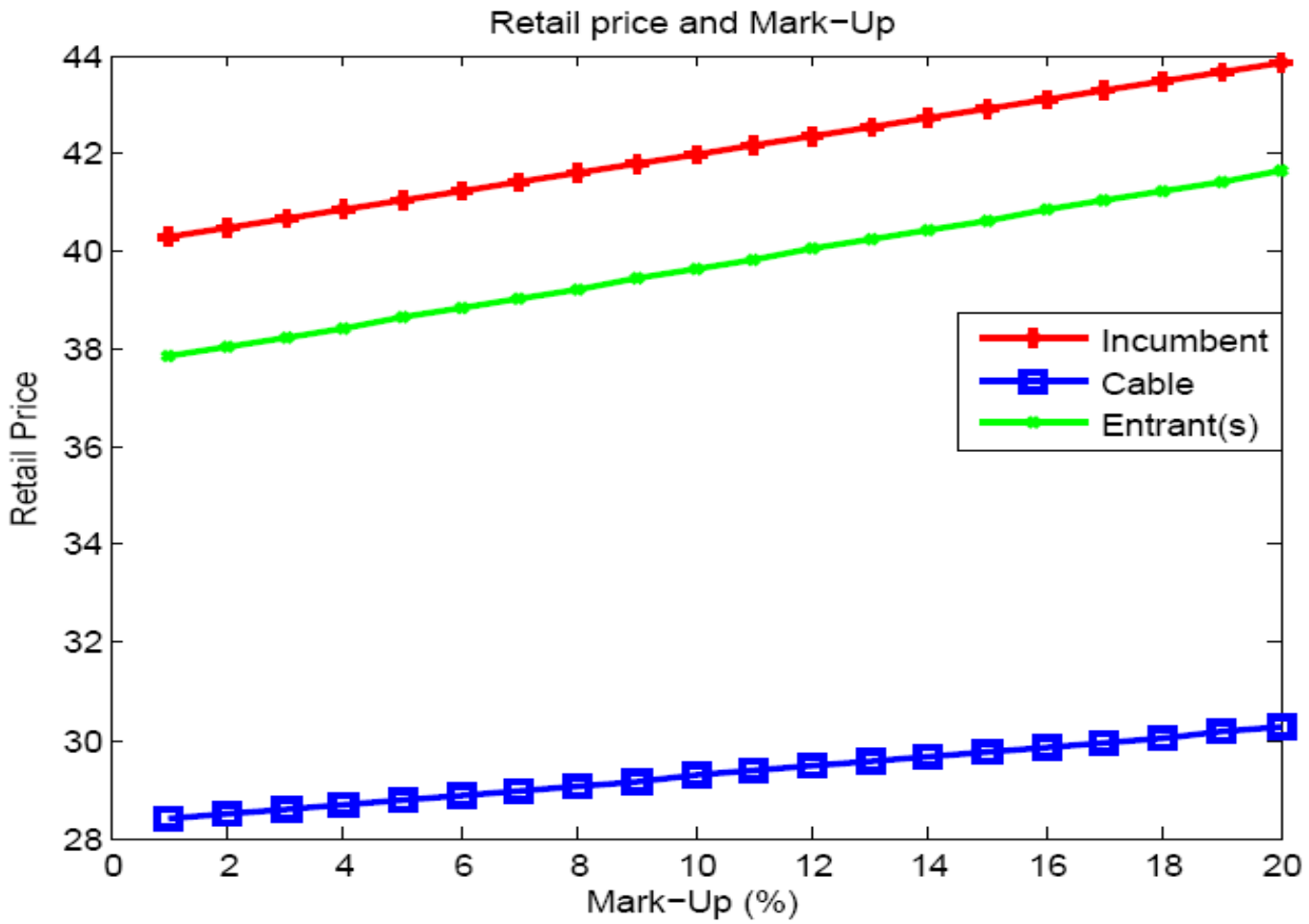
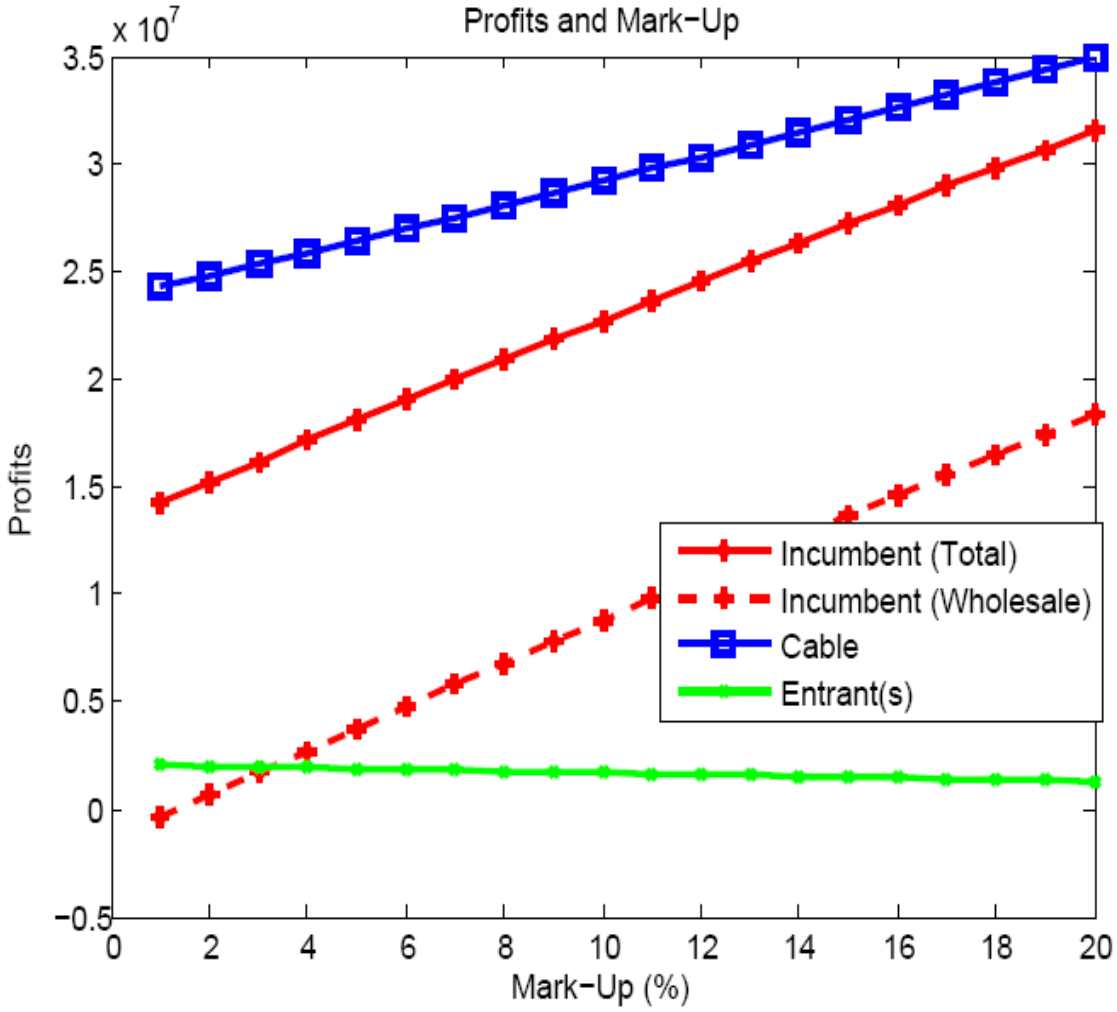
Price increases through access mark-up: Almost 1:1 for fibre carriers! Cable benefits! Scenario: GPON bitstream access at core



Profit effects of access mark-up: Incumbent and cable win, entrants lose
Scenario: GPON bitstream access at core



Overestimating wholesale costs would have huge impacts on the market.

Conclusions

Unbundling scenarios (P2P & WDM PON) generate greater consumer surplus and total welfare than GPON and bitstream access.

GPON is only ~10% cheaper than Ethernet P2P. Coverage is nearly the same. Benefits of Ethernet P2P deliver higher consumer surplus and total welfare than bitstream only GPON.

Proper pricing for wholesale access is essential, especially for LLU. Entrants' critical market shares, viability and competitive coverage are sensitive even to minor variations.

Under certain conditions, WDM PON could be the best choice if that technology becomes commercially available for the access network.

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Policy Conclusions

There should be a major policy concern over the basic passive topology of future fibre networks. This is because topology determines the intensity of competition and the performance of the market in the NGA environment.

If topology choices rest solely with the incumbent they, and not the policy-makers, will determine the scope of future competition.

A P2P topology provides the greatest variety of technology choices for market participants. Only it ensures the principle of technological neutrality for those active fibre technology choices and all relevant options.

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Policy Conclusions

Our results show that the superior fibre scenarios in terms of welfare and consumer surplus are also the ones that offer the best prospect for meaningful competition on the basis of unbundling. This is a win-win situation.

The higher investment cost of a P2P topology are more than outweighed by the welfare effects of the business models based on this topology and its innovative and dynamic advantages. This holds for incumbents as well as for their competitors

Governments and banks that provide public funding for deploying fibre networks as well as competition authorities and NRAs should take account of these findings when making decisions regarding fibre networks.

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Policy Conclusions

Incumbent topology and technology choice

Competitor technology options

	Incumbent GPON	Incumbent P2P	Incumbent WDM PON
Bitstream access	X	X	X
Ethernet P2P	-	X	X (wavelength unbundling)
GPON	X (subloop)	X	X (subloop)
Active Ethernet	X (subloop)	(X)	X (subloop)
WDM PON	X (subloop)	X	X (subloop)

Subloop access usually economically not viable

GPON and WDM PON might coexist in wavelength grid

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BACK UP

The country considered is „Euroland“

Geotype	Cluster ID	Potential customers per km²	Total potential customers per cluster	Share of total customers	Potential customers (cumulated)	Number of MDF	Potential customers per MDF	Average trench length per potential customer (m)
Dense urban	**1**	4000	1.763.916,00	8%	1.763.916,00	69,00	25.564,00	2,4
Urban	**2**	1600	2.163.672,00	10%	3.927.588,00	168,00	12.879,00	5,4
Less Urban	**3**	800	2.646.000,00	12%	6.573.588,00	252,00	10.500,00	7,8
Dense Suburban	**4**	470	2.062.480,00	9%	8.636.068,00	280,00	7.366,00	10,2
Suburban	**5**	280	2.460.360,00	11%	11.096.428,00	303,00	8.120,00	13,1
Less Suburban	**6**	150	2.989.056,00	14%	14.085.484,00	417,00	7.168,00	17,4
Dense Rural	**7**	60	4.331.208,00	20%	18.416.692,00	1.421,00	3.048,00	28,6
Rural	**8**	< 60	3.448.368,00	16%	21.865.060,00	2.488,00	1.386,00	55,1
			21.865.060	**100%**		**5.398**		

Representative geo-type clusters based on geo-data of actual EU countries

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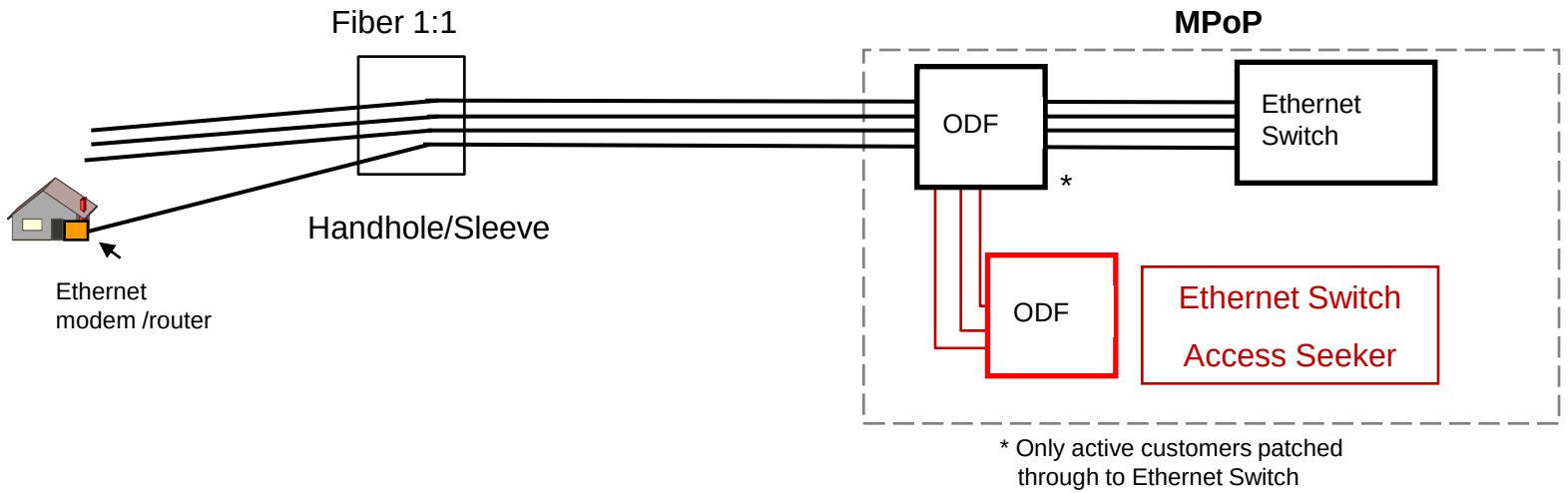
Unbundling of FTTH/P2P



* Only active customers patched through to Ethernet Switch

Incumbent cost (relevant for LLU price)

- CPE
- Access Network incl. Inhouse cabling
- ODF + Patch cabling + floorspace
- Ethernet Switch + floorspace + energy
- Network sided Ethernet port (1 per MPoP)

- Concentration Network
- Core Network

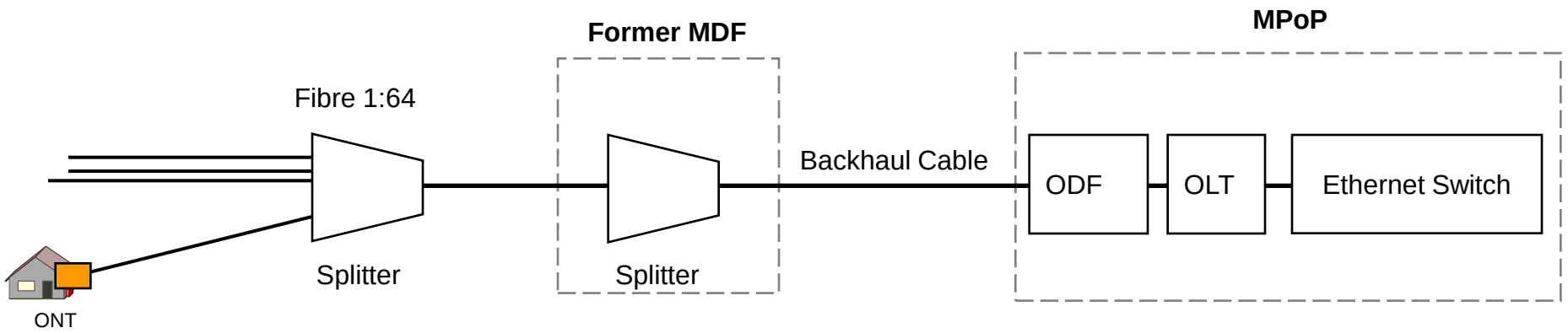
Competitor cost**

- CPE
- LLU charge
- Competitor‘s ODF & Patch cabling + floorspace
- Ethernet Switch + floorspace + energy
- Network sided Ethernet port (1 per MPoP)

- Concentration Network
- Core Network

** Assumption: Unbundler operates Ethernet P2P network

WDM PON with bitstream access at core level



Incumbent cost (relevant for wholesale price)

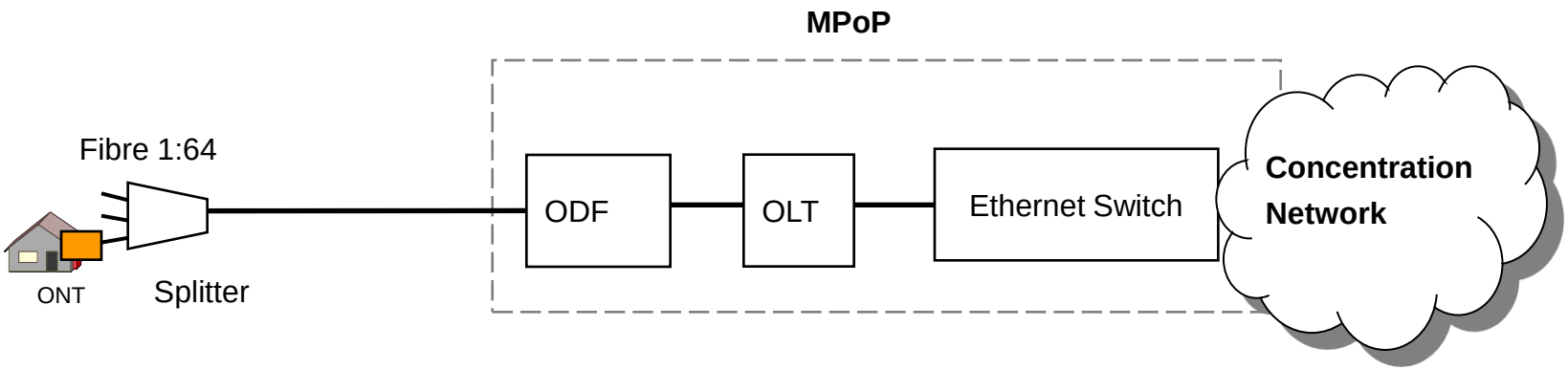
- CPE
- Access Network incl. inhouse cabling and backhaul from MDF to MPOP
- ODF + Patch cabling + floorspace
- OLT + floorspace + energy
- Ethernet Switch + floorspace + energy
- Network sided Ethernet port (1 per MPoP)*
- Core Network

Competitor Cost

- CPE
- WDM PON wholesale charge
- Network sided Ethernet port (1 per MPoP)*
- Small collocation space
- Core Network

*Network sided port of Ethernet Switch is not part of wholesale charge per subscriber.

GPON bitstream access at core level



Incumbent cost (relevant for bitstream price)

- CPE
- Access Network incl. inhouse cabling
- ODF + Patch cabling + floorspace
- OLT + floorspace + energy
- Ethernet Switch + floorspace + energy
- Concentration Network

- Core Network

Competitor cost

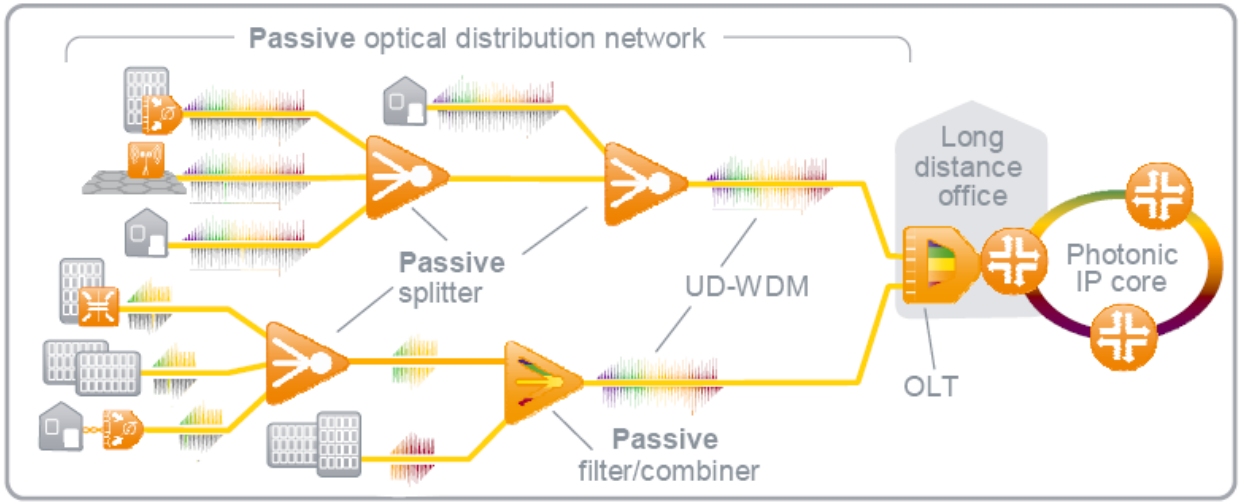
- CPE
- Bitstream wholesale charge
- Network sided Ethernet port (1 per MPoP)

- Core network

Future technology option: WDM PON based on Point-to-Multipoint fibres

Next Generation Optical Access – NGOA[1)]

Shaping the colorful future of broadband access



One wavelength per customer: unshared 1Gbps symmetrical

Up to 100 km reach[2)] and high splitting factor of ≤ 1000 [2)]

Reuse of existing metro fibre – convergence of access and metro aggregation

1) Nokia Siemens Networks research project
2) depending on choice of cascaded splitter / filter design

Curt Badstieber

Nokia Siemens Networks

Concentration network replaced

MDF remains as passive network node

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Assumptions on key cost drivers

Direct Invests

Element	Invest per unit	Lifetime (years)
Ethernet CPE*	100€	5
GPON CPE*	115€	5
WDM PON CPE*	172,50€	5
Inhouse fibre cabling	366,43€ per subscriber	20
ODF port / patch cabling	23€ / 11€	20
OLT	1000€	7
WDM PON OLT	5000€	7
Ethernet Port 1Gbps / 10Gbps	120€ / 2000€	7
Trenches, ducts…	See later slide	20

*plug & play

Direct Costs and other parameters

Element	Assumption
National concentration network cost per month	6mn € + 0,092€ per subscriber
National core network cost per month	7mn € + 1,32€ per subscriber
Retail cost (customer care, billing, sales & marketing, customer acquisition)	5€ per subscriber per month
WACC	10%

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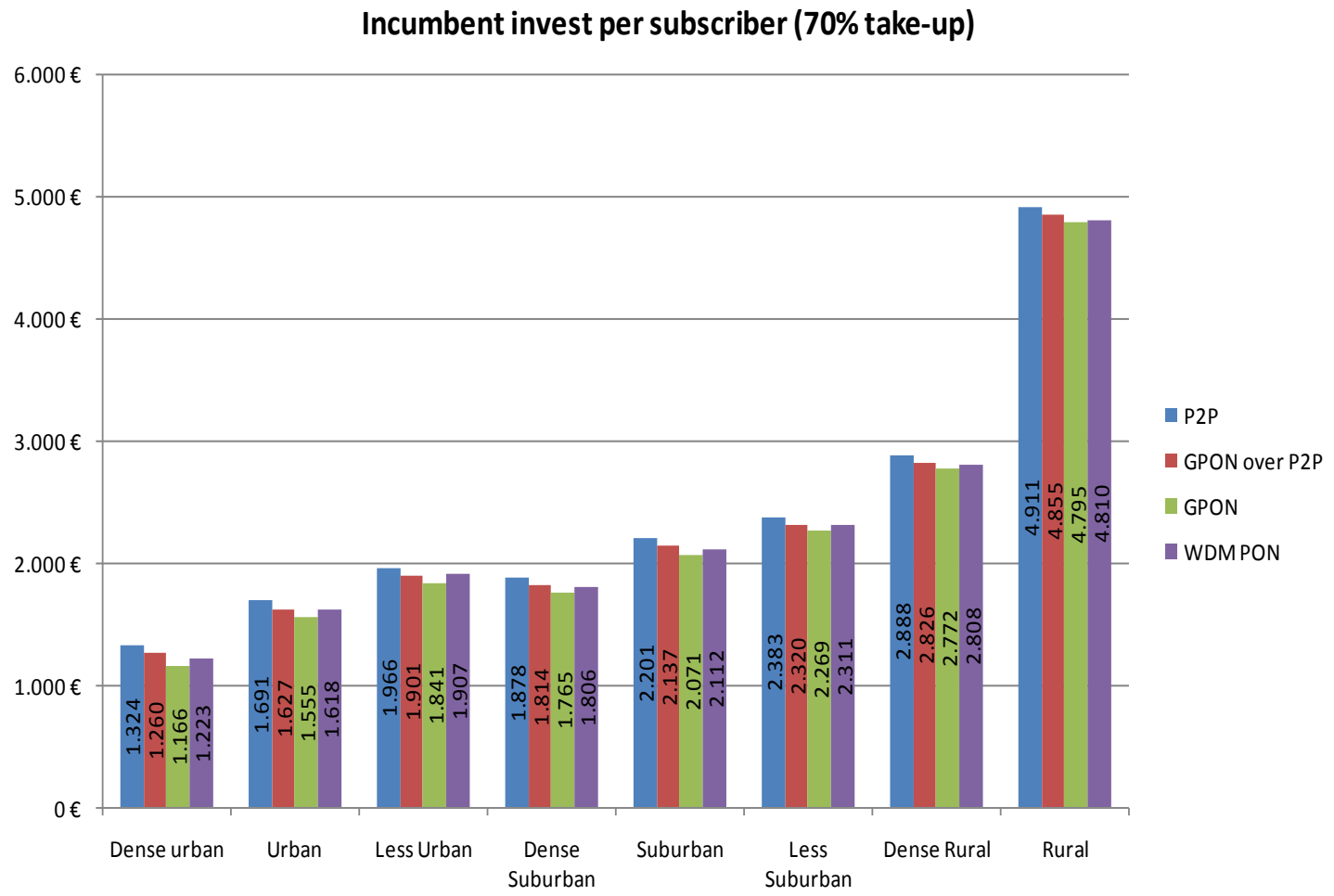
Investment increases with decreasing density. The level of investments does not differ much between architectures



Networks that can be unbundled are superior to bitstream-only GPON in terms of consumer surplus and welfare

– Ethernet P2P, GPON over P2P and WDM PON generate greater monthly consumer surplus and total welfare than GPON-based bitstream

	Hinterland ("no-cable")					No-Hinterland ("cable")				
		Consumer Surplus		Total Welfare			Consumer Surplus		Total Welfare	
Scenario	n-1	mn €	Rank	mn €	Rank	n-2	mn €	Rank	mn €	Rank
P2P unbundling	3	243.1	2	279.2	2	4	466.9	1	490.3	2
GPON over P2P unbundling	3	245.6	1	283.6	1	3	434.0	2	493.8	1
WDM PON unbundling	4	240.5	3	270.8	3	4	431.2	3	473.9	3
GPON Bitstream Core	4	216.8	4	247.7	4.5	4	400.5	5	445.7	4.5
GPON Bitstream MPoP	3	208.6	5	245.4	4.5	4	416.0	4	445.1	4.5

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Marginal costs and prices in Euroland
(in Euro per month)

Scenario	MC_I perceived	p_I	MC_E	p_E	MC_C	p_C
P2P unbundling	34.36	42.07	36.22	42.37	12	23.76
GPON over P2P unbundling*)	32.22	43.58	36.22	45.54	12	27.92
WDM PON unbundling	33.37	41.24	34.00	39.32	12	26.16
GPON bitstream core	31.99	40.10	32.62	37.63	12	28.28
GPON bitstream MPoP	31.53	38.76	32.16	37.67	12	27.15

***) One less fibre entrant!**

I – Incumbent, E – Entrant, C - Cable

Sensitivity to W and CS to WtP assumptions, in million Euro

- Rankings of basic model in Euro are confirmed by sensitivities on QoS, Willingness to Pay, incumbency advantage: unbundling scenarios always ranked well above bitstream-only scenarios
- Sensitivities show that it is less clear which unbundling technology should be preferred

	P2P unbundling		GPON over P2P unbundling		GPON bitstream core		GPON bitstream MPoP		WDM PON unbundling	
	CS	W	CS	W	CS	W	CS	W	CS	W
Basic model	467	490	434	494	400	446	416	445	431	474
WDM PON with alternative cost									490	513
Increased incumbency advantage	410	471	413	474	380	428	360	426	411	456
Smaller spread	454	513	457	517	489	513	478	507	500	522
Increased incumbency advantage and smaller spread	434	494	437	498	448	493	422	487	459	503

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