Towards Technologically and Competitively Neutral Fiber to the Home (FTTH) Infrastructure

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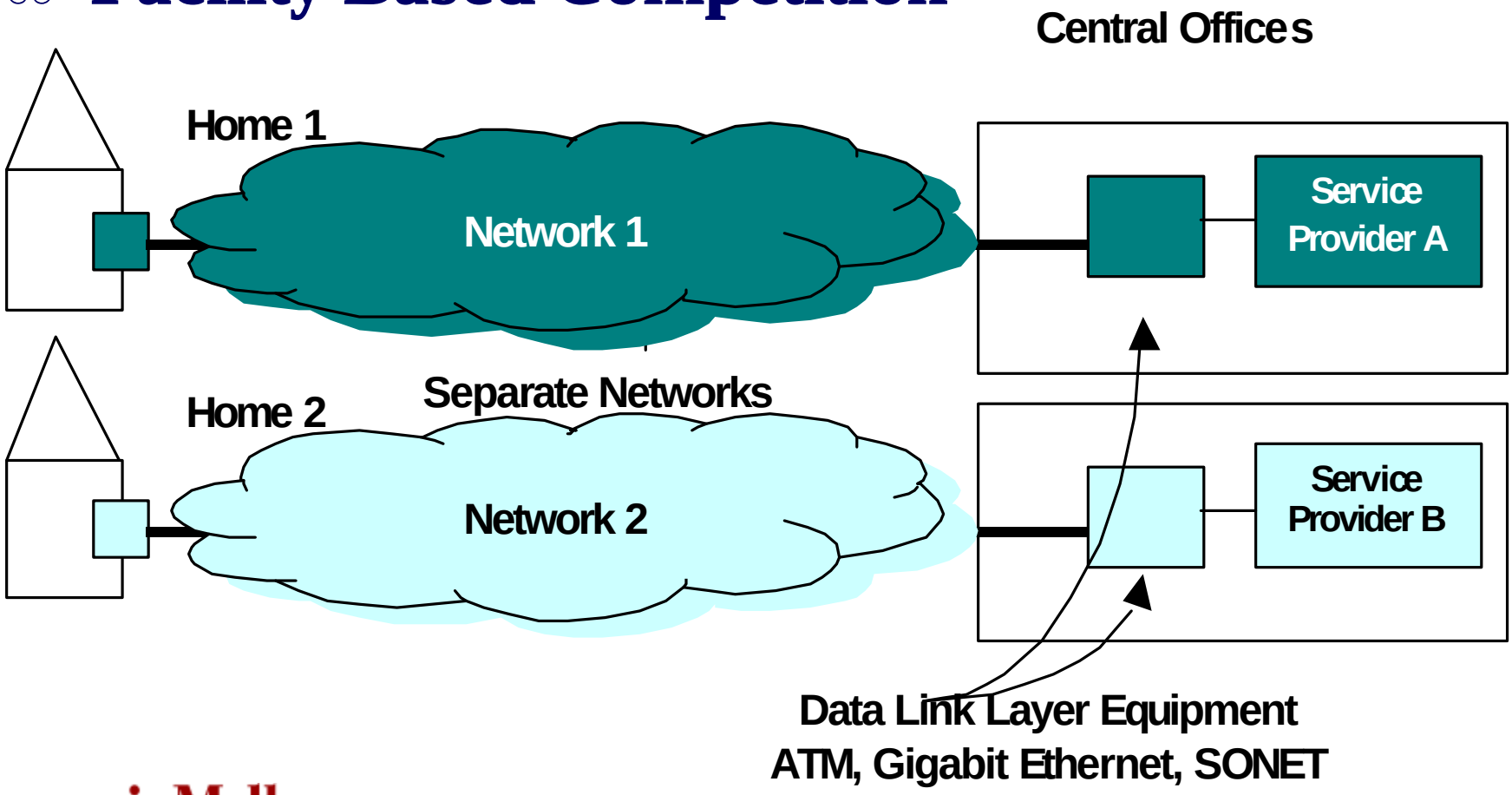
Background

- **Telecommunications Act of 1996**
  - Competition in the 'Last Mile'
  - Broadband Access
  - Universal Access

- **In the context of FTTH, what does it take to have competition in the 'last mile'?**

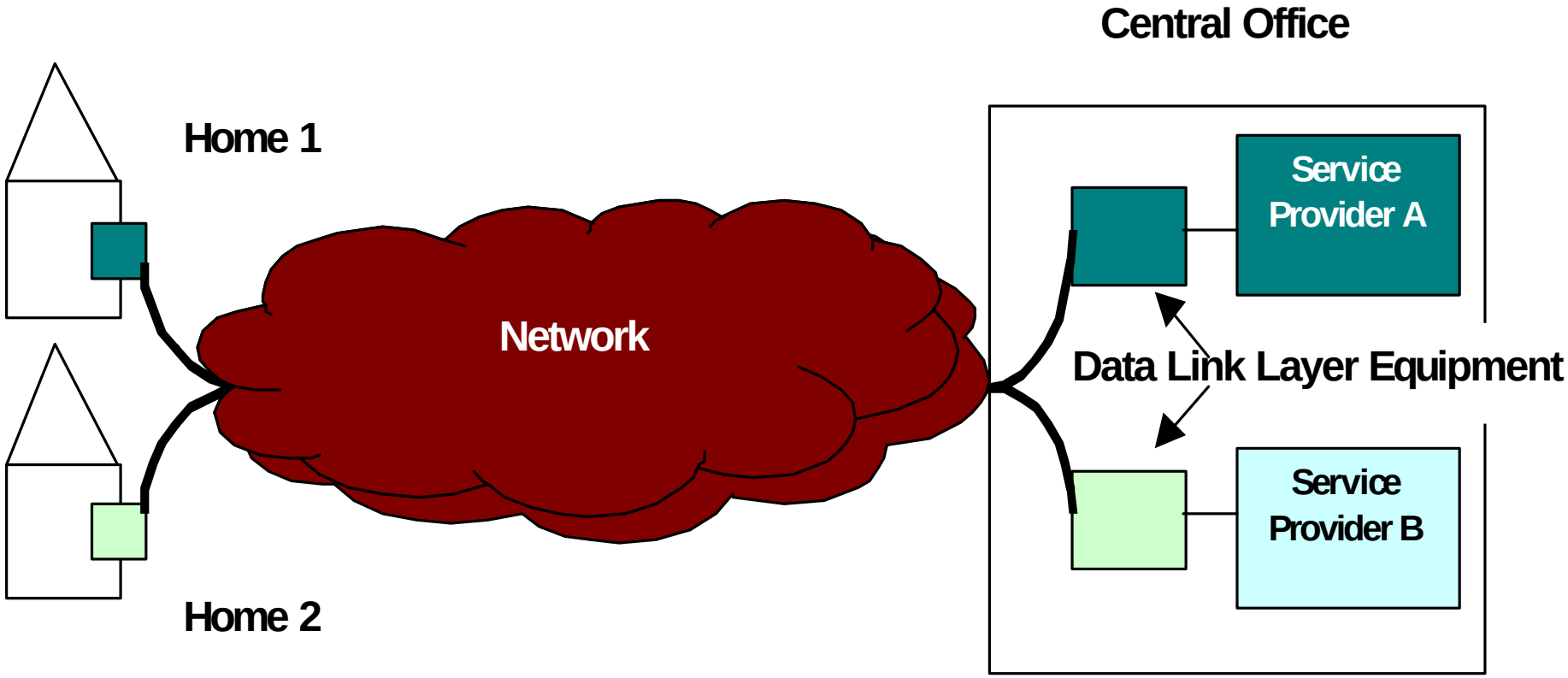
Models of Competition in Telecommunications

Facility Based Competition



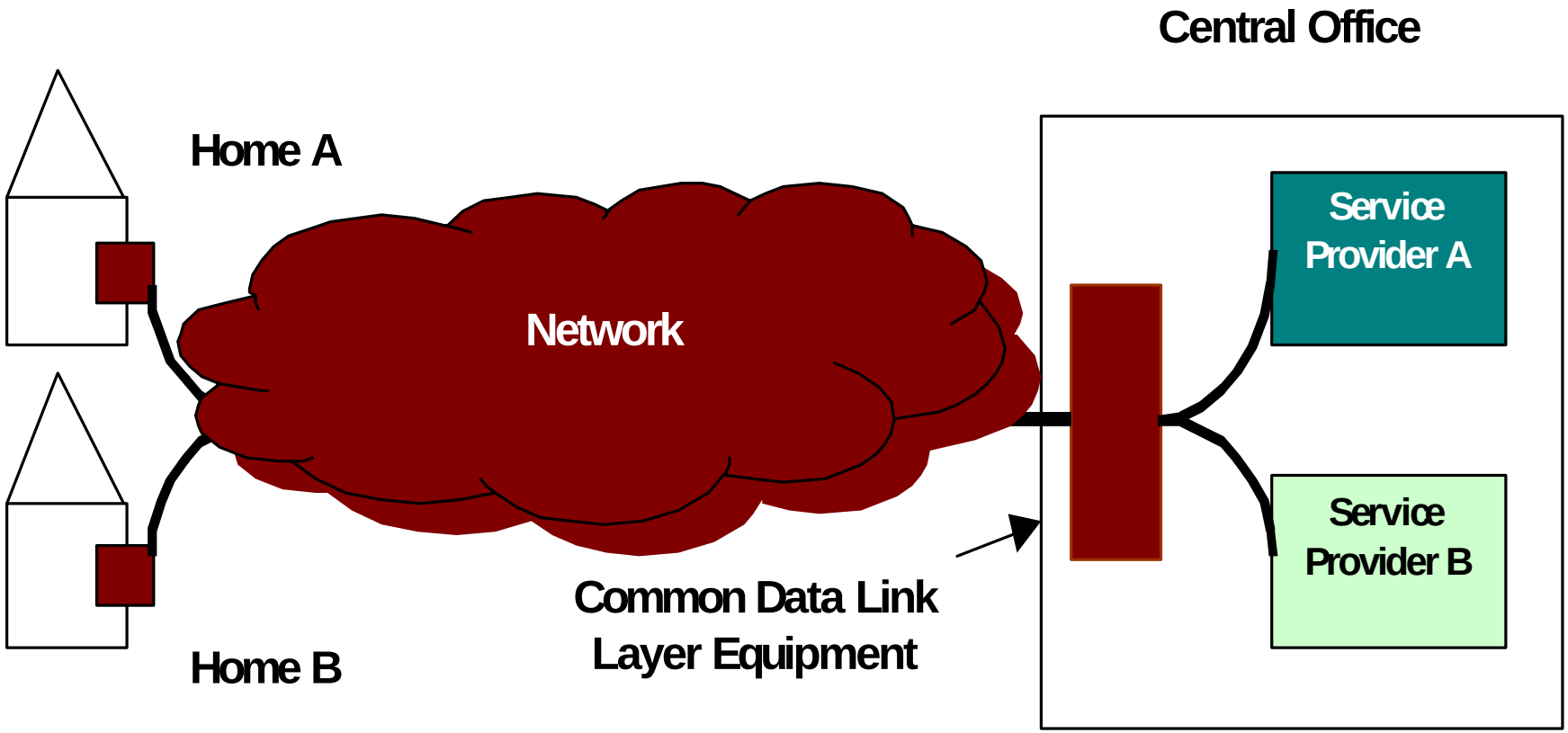
Models of Competition in Telecommunications

UNE Based Competition



Models of Competition in Telecommunications

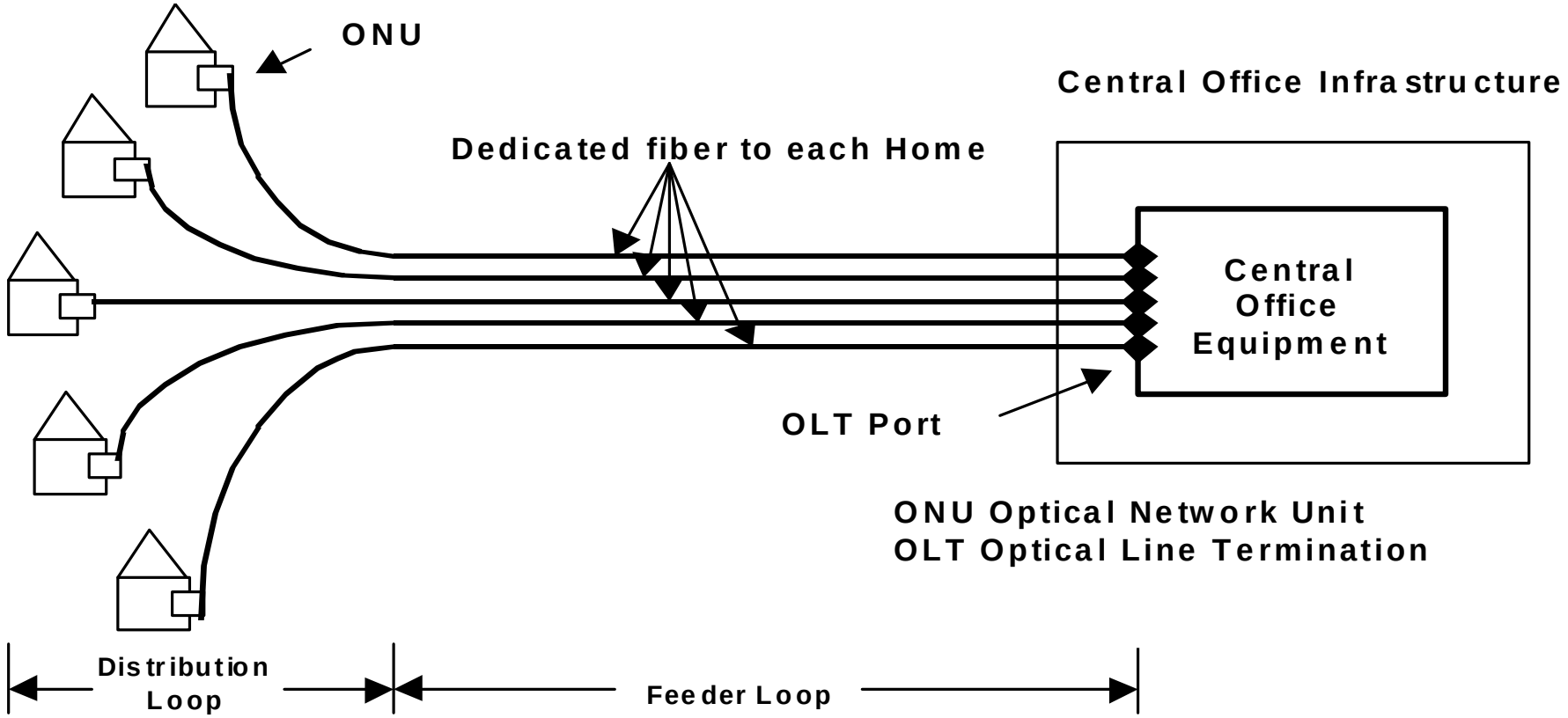
Open Access Based Competition



FTTH Architectures

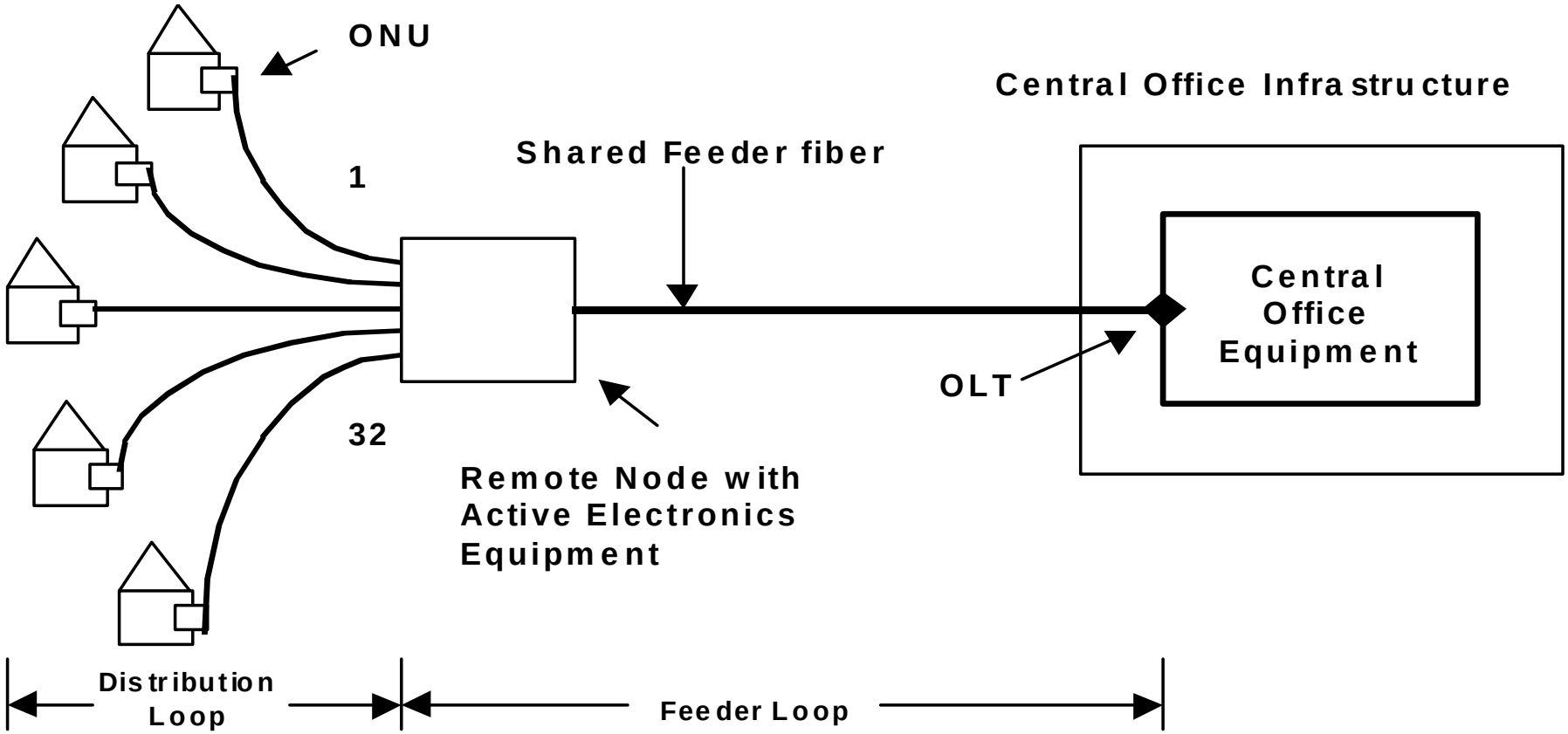
- **Home Run**
- **Active Star**
- **Passive Star (Passive Optical Network - PON)**
- **Wavelength Division Multiplexed Passive Optical Networks (WDM PON)**

Home Run Architecture



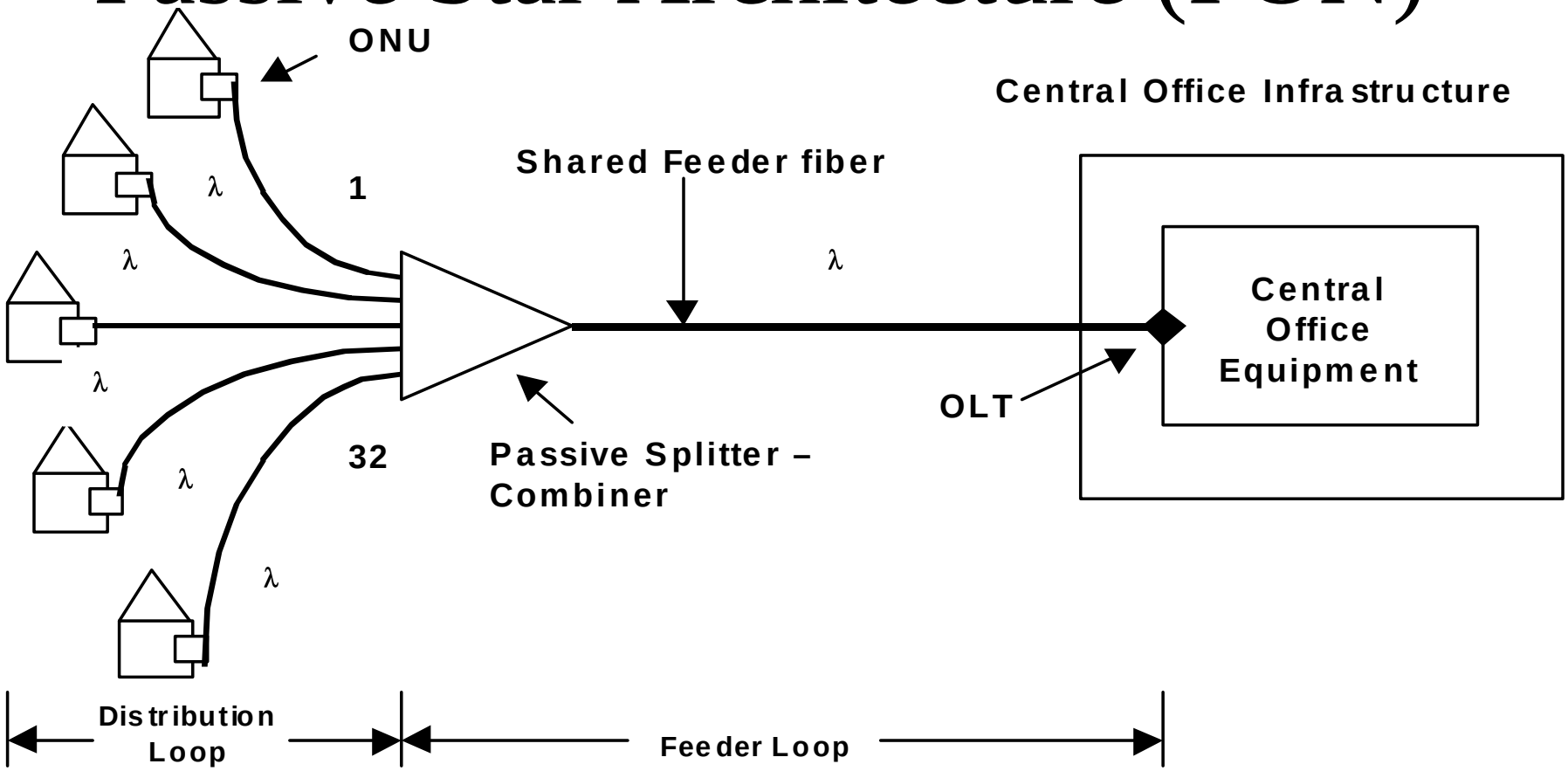
Architecture	Brief Description	Shared Infrastructure
Home Run	Dedicated fiber from the Central Office to each Home	Central Office

Active Star Architecture



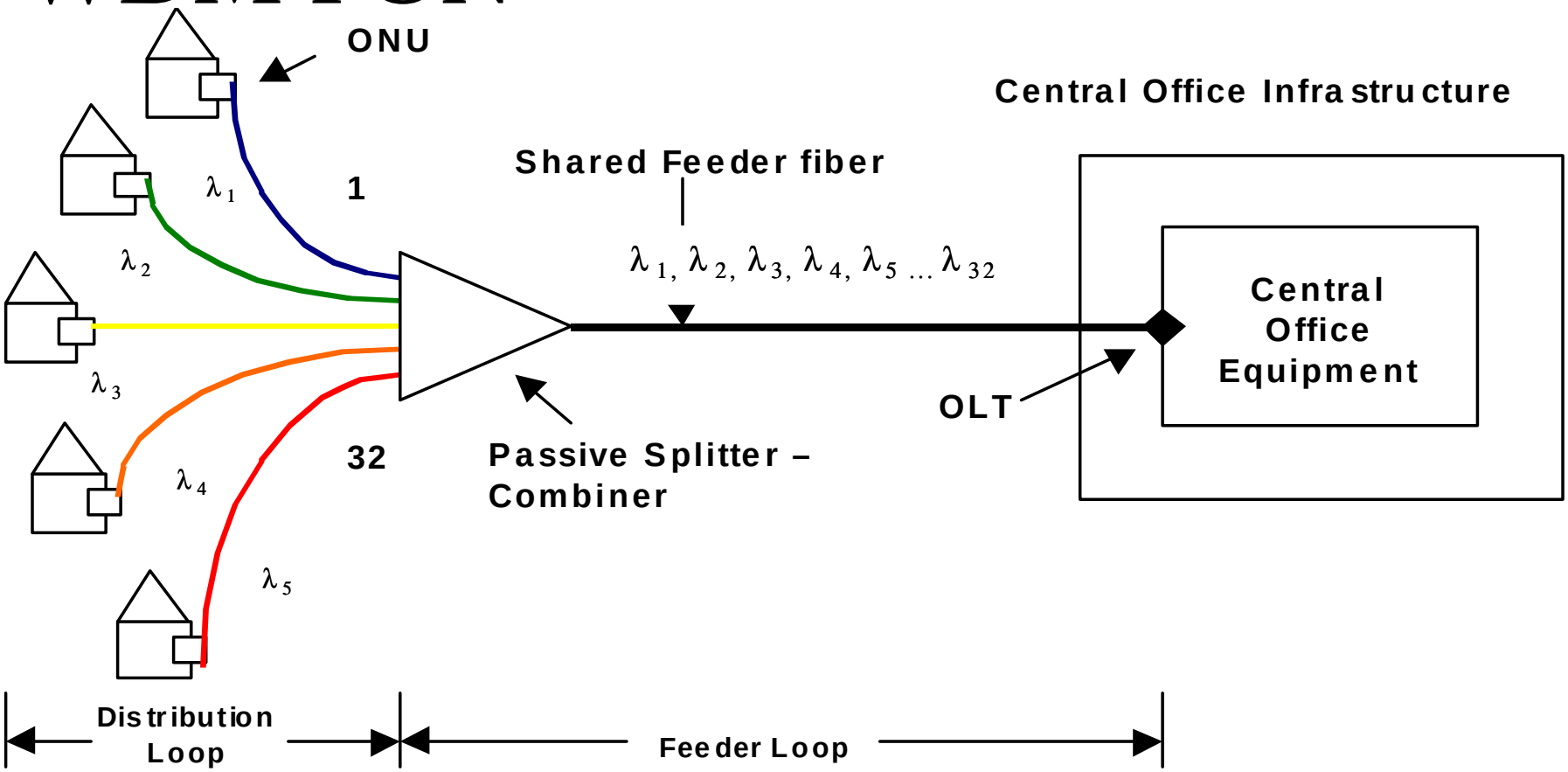
Architecture	Brief Description	Shared Infrastructure
Active Star	Signals multiplexed at Remote Node that lies between Central Office and Home	From theCentral Office to the Remote Node

Passive Star Architecture (PON)



Architecture	Brief Description	Shared Infrastructure
Passive Star	Signal's power optically split at Remote Node; Remote Node not powered	From Central Officet to Remote Node

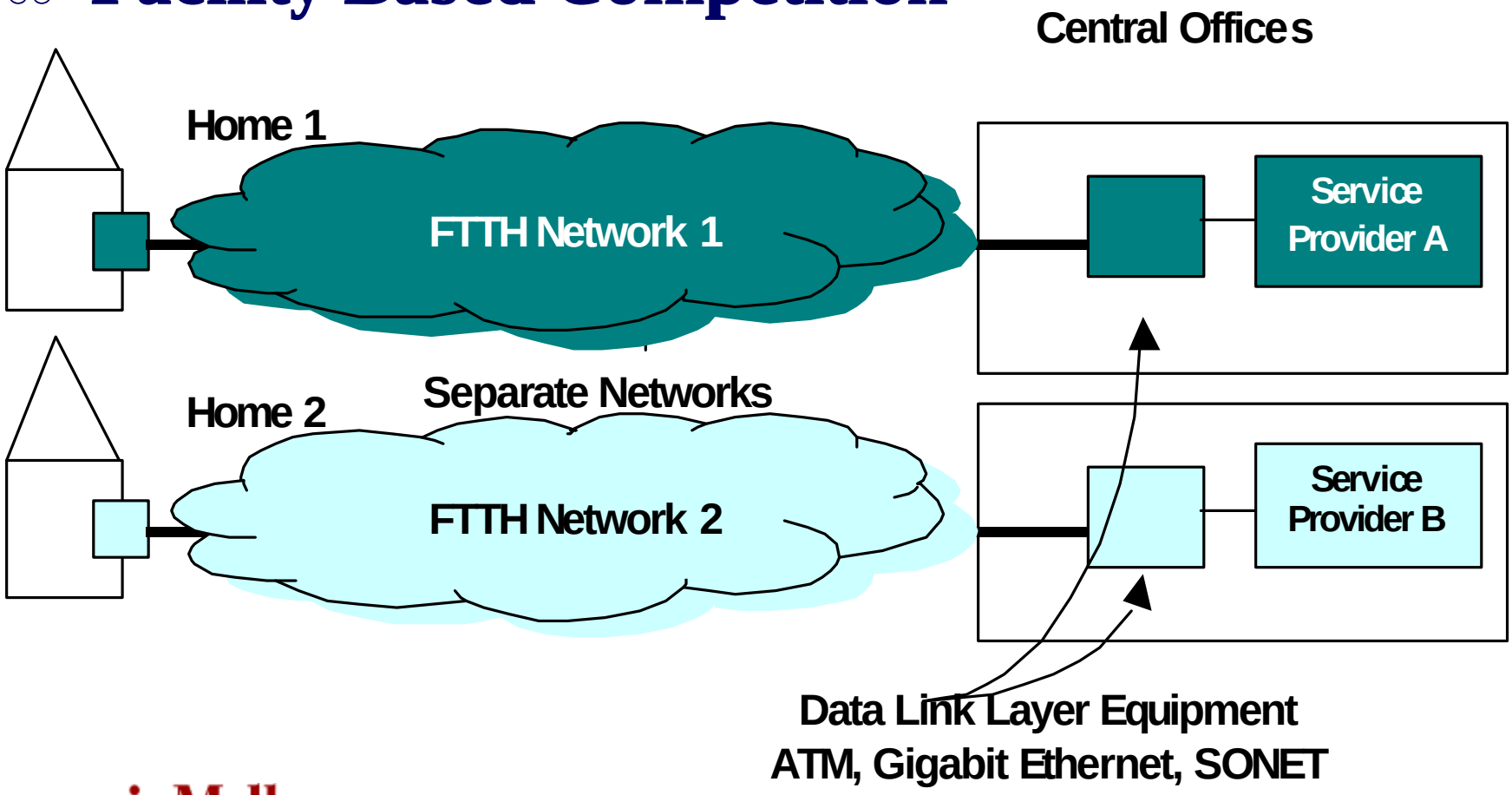
WDM PON



Architecture	Brief Description	Shared Infrastructure
WDM PON	Signal's power optically split at Remote Node; Feeder fiber carries multiple wavelengths	From Central Officet to Remote Node

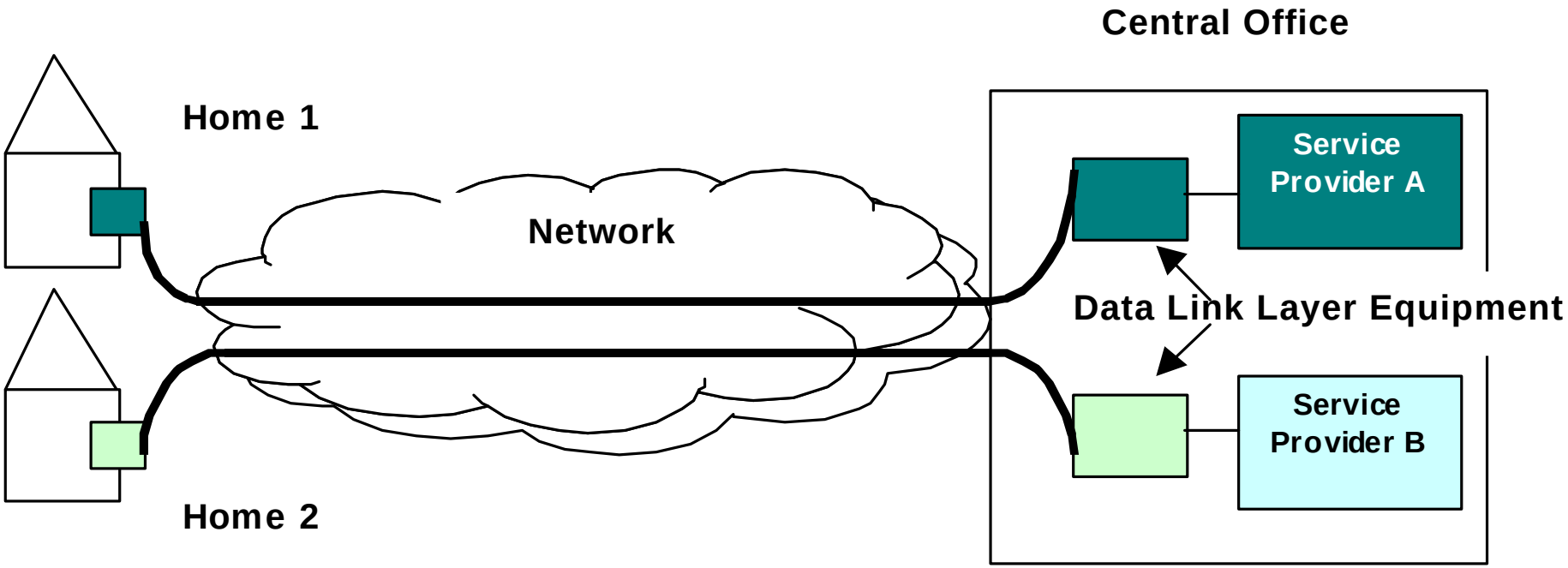
Competition in FTTH

Facility Based Competition



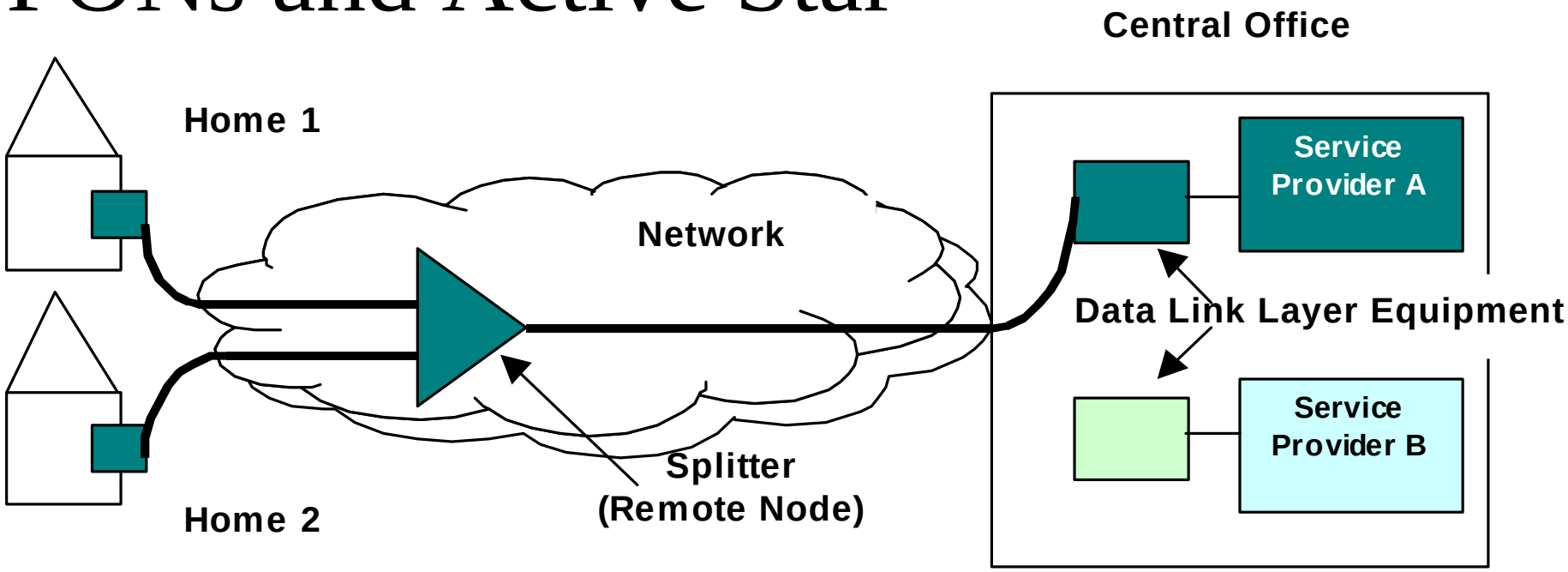
Non facilities based Competition in Home Run Fiber

- **Individual Fiber can be rented out as a UNE**



- **Home Run Fiber supports Competition at the Data-Link layer and in Higher layers services**

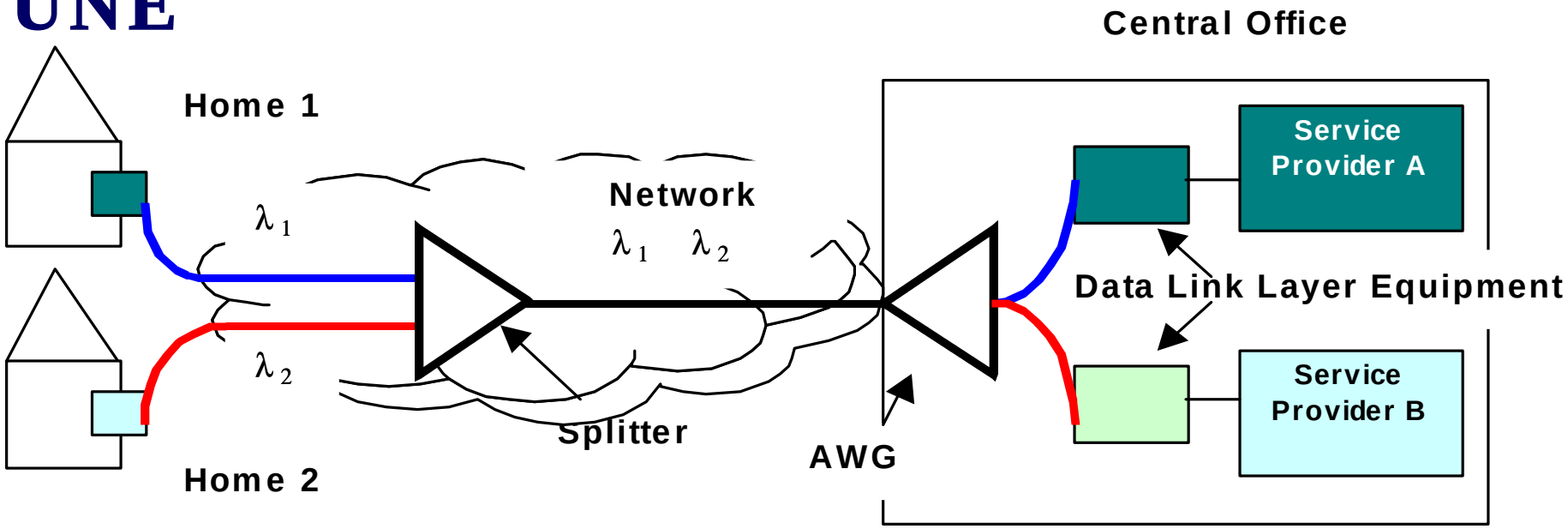
Non facilities based Competition in PONs and Active Star



- **PONs (and Active Star) do not support Competition at the Data-Link layer; they support Competition in Higher layers services**

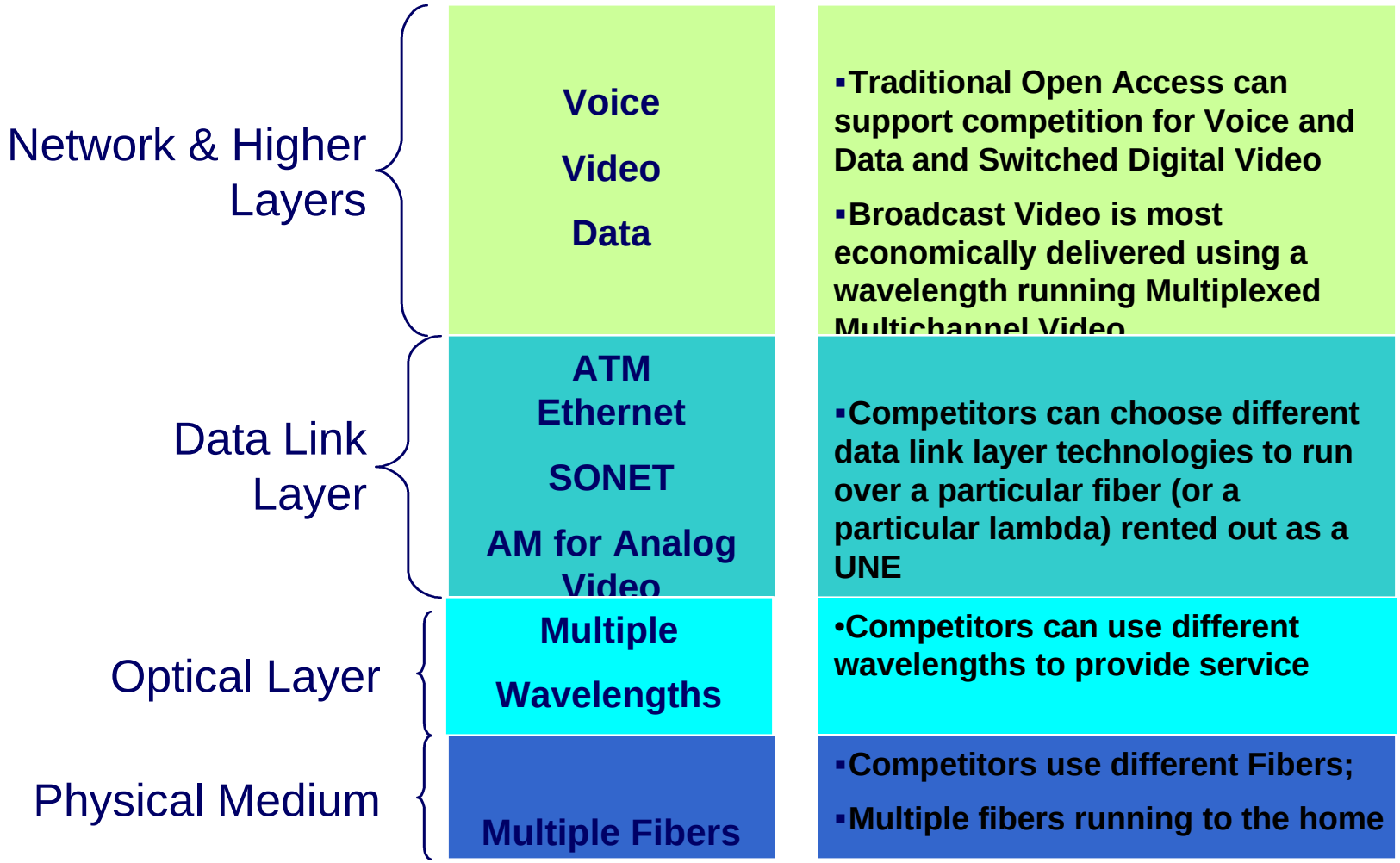
Non facilities based Competition in WDM PONs

- **Individual Wavelength can be rented out as a UNE**



- **WDM PONs support Competition at the Data-Link layer and in Higher layers services**

What do we mean by Competition in the 'Last Fiber Mile'?



Architectures and Competition

	Home Run	PONs	Active Star	WDM PONs
Competition in Data Link Layer Services	Easy	Hard	Hard	Easy
Competition in Voice, Data, Digital Video	Neutral	Neutral	Neutral	Neutral
Competition in Broadcast Video	Easy	Hard	Hard	Easy
Cost per Home Served	?	?	?	?

Economic Feasibility of Competition

- **General Perception:** Home Run Fiber is more expensive than PONs; WDM PONs are not economically feasible today
- **Our arguments:** Home Run Fiber enables Data-Link layer competition while PONs do not
- **Research Questions:**
  - By how much is Home Run Fiber more expensive than PONs?
  - Which forms of competition are Economically Feasible?

FTTH Engineering Cost Model

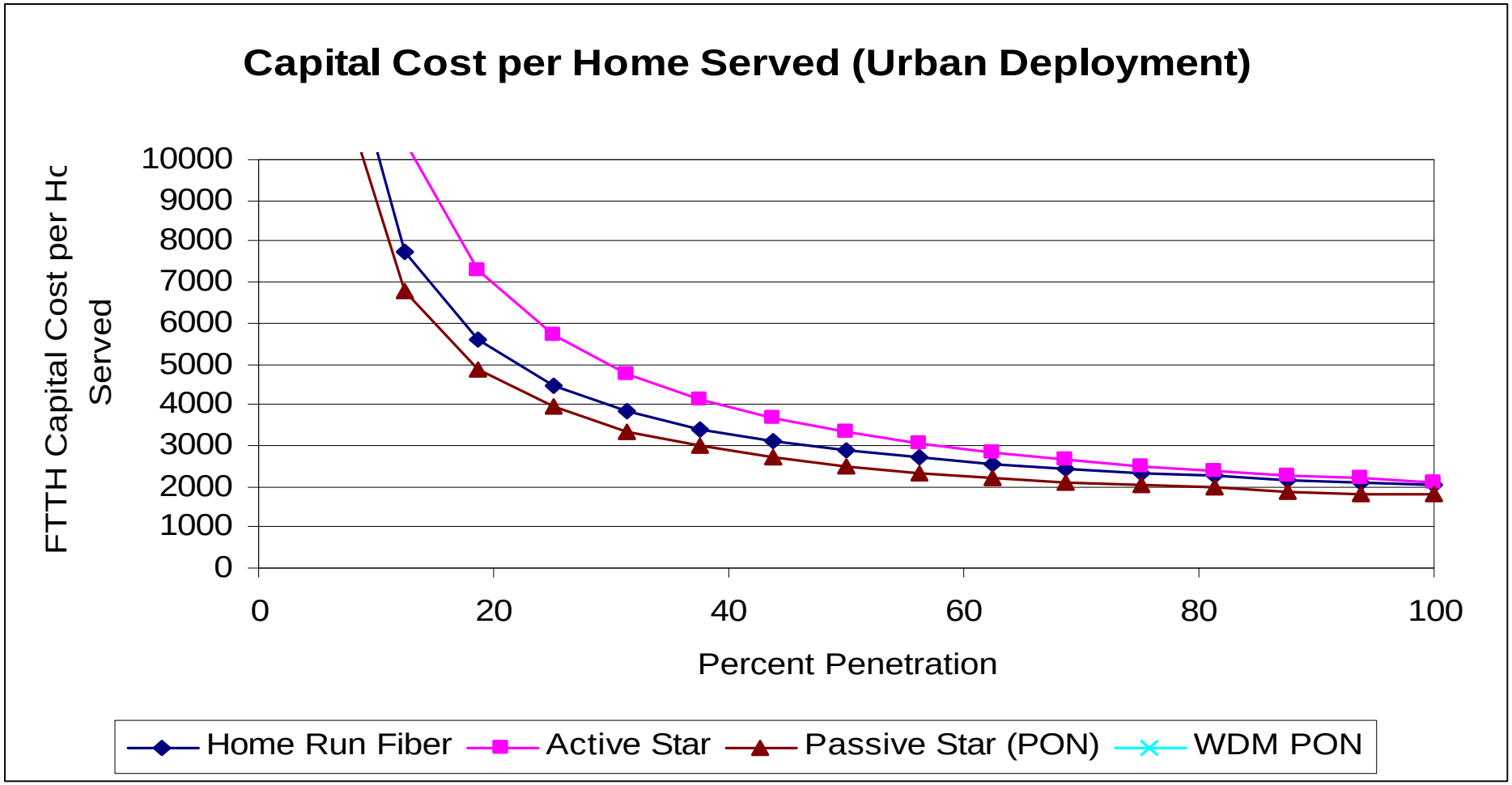
Deployment	Homes per sq. mile	Homes served per CO
Urban	3389	16,135
Suburban	1602	16,201
Small Town	217	10,184
Rural	85	5,871
Remote Rural	20	3,018

FTTH Engineering Cost Model

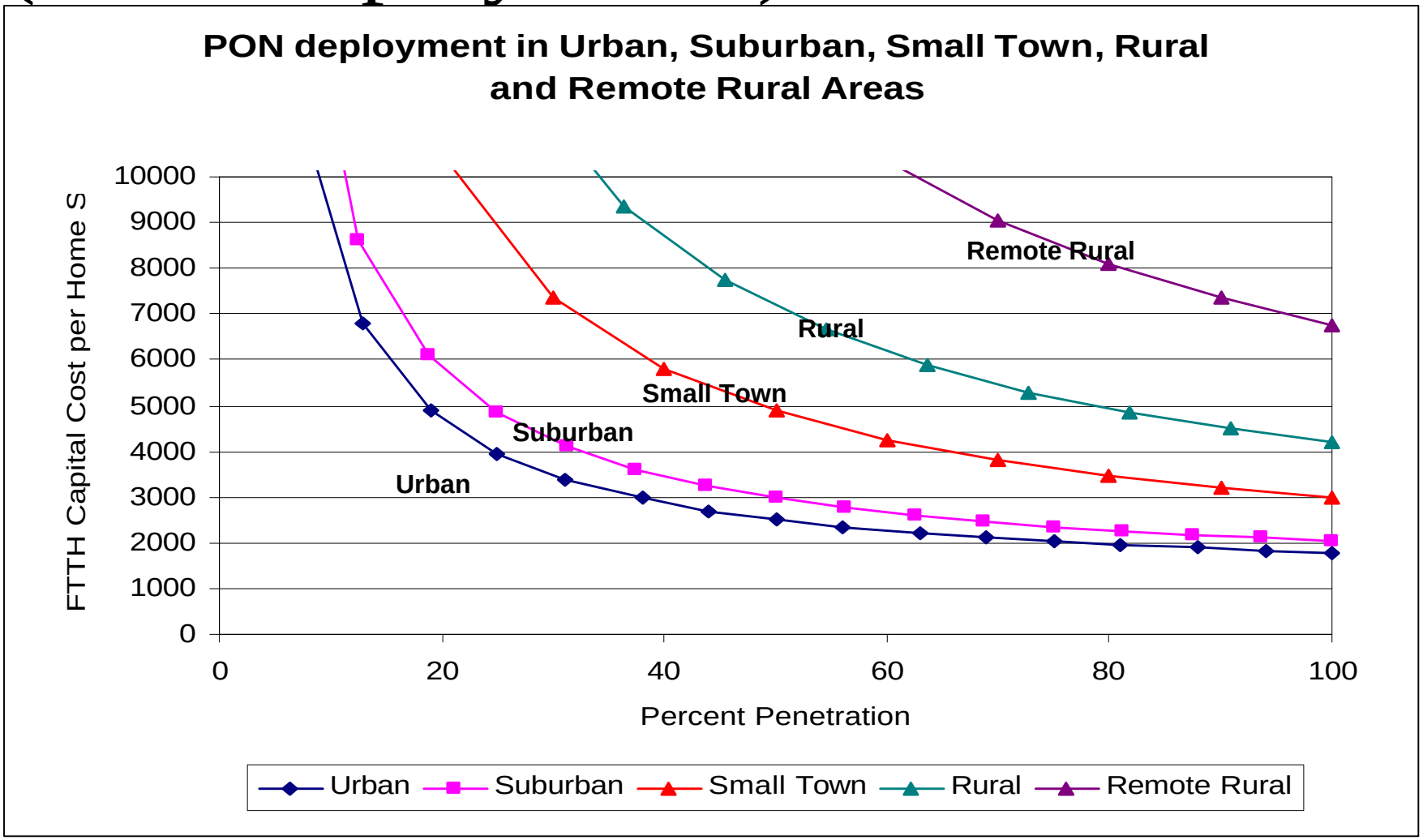
Architecture	OLT Interface
Home Run	100 Mbps Fast Ethernet per Home
Active Star	Gigabit Ethernet Interface per 32 Homes
PON	Gigabit Ethernet Interface per 32 Homes
WDM PON	100 Mbps Fast Ethernet per Home

ONU Interface
2 POTS ports, 10/100 Base T, RF Video

Capital Cost per Home Served (Urban Deployment)



Capital Cost per Home Served (PON Deployments)



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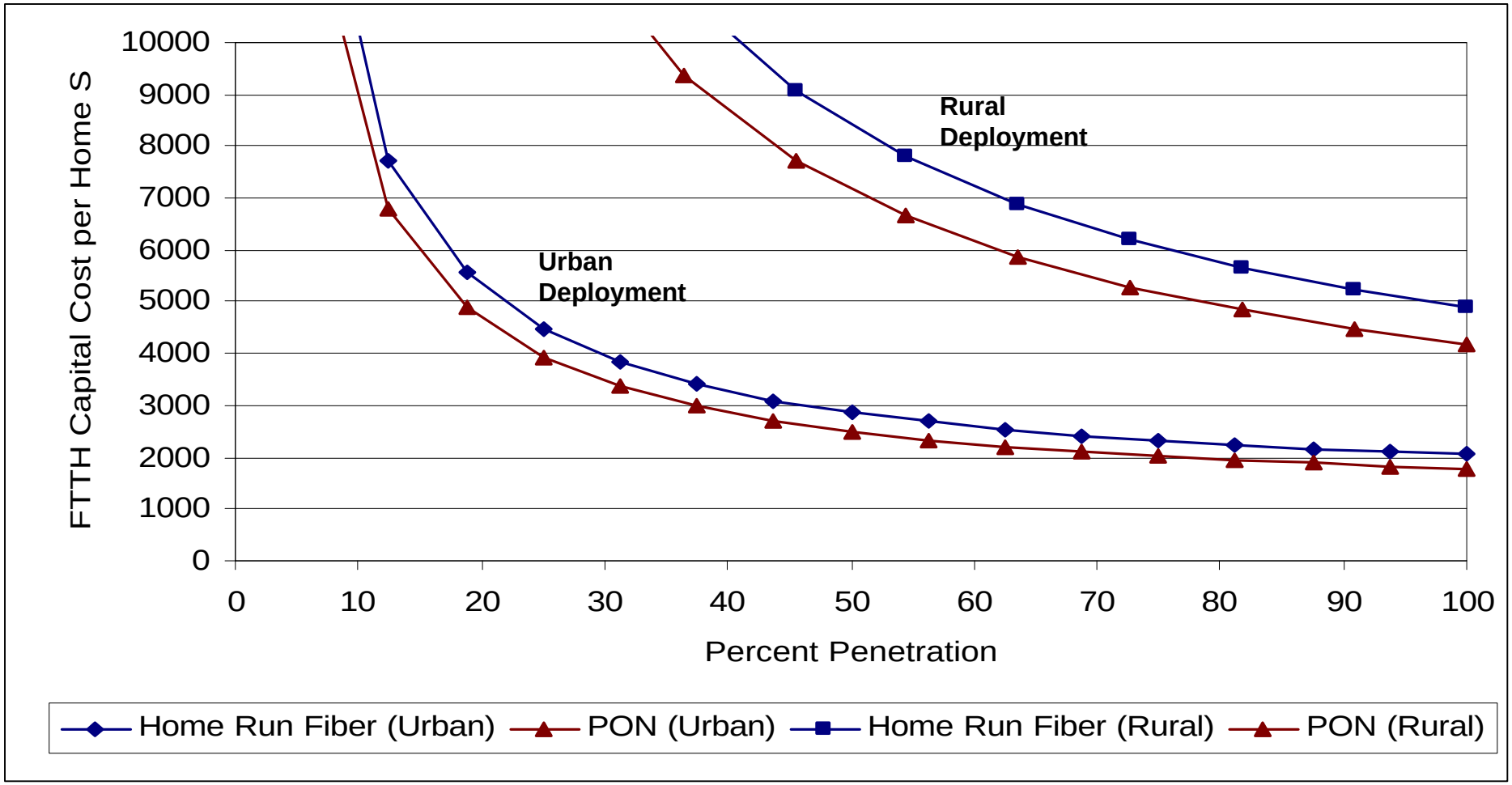
Capital Cost per Home Served

Urban and Rural Deployments



Competition in FTTH: Economic Feasibility

- **Facilities based Competition is unlikely as FTTH is a decreasing cost industry**
- **Wavelength based competition is infeasible in the near future**
- **Data Link Layer Competition (and competition in Broadcast video) is easy in Home Run architecture and hard in PONs; and therefore has an economic premium**
- **Competition in Data, Voice and Switched Digital Video is easy in all architectures**

The ‘Cost’ of Data-Link layer Competition..

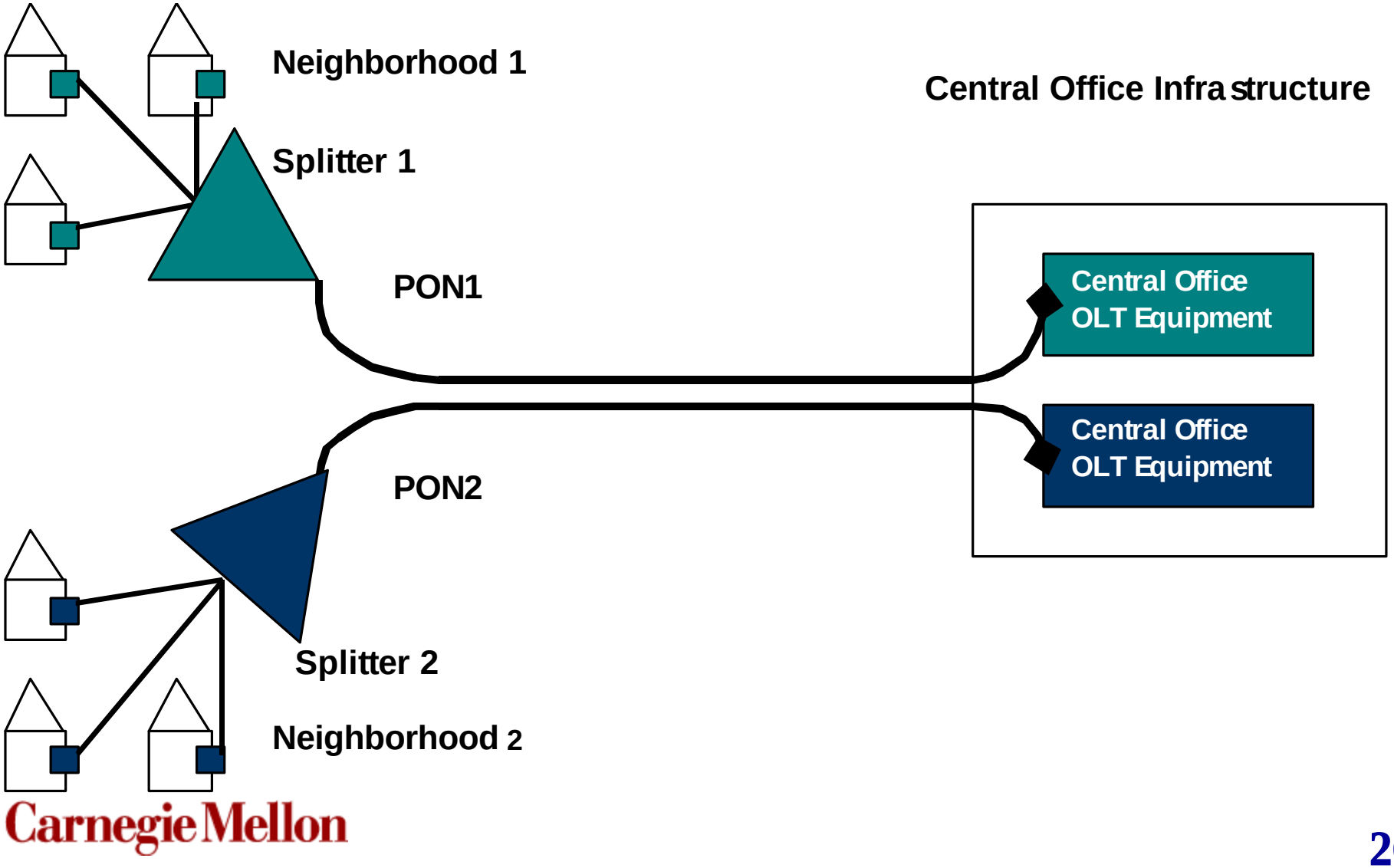
- **Cost Difference (per Home) between Home Run Fiber and PON**

Deployment Scenario	Cost of Competition per Home Served ($) @ 100% penetration
Urban	270
Suburban	350
Small Town	510
Rural	690
Remote Rural	560

Towards Economically Efficient and Competitive Neutral FTTH Infrastructure

- **Home Run Fiber is Competitively Neutral..**
- **But is it 'economically efficient'?**
- **Can we have Data-Link layer at a lower cost than Home Run Fiber?**

A Traditional PON Deployment



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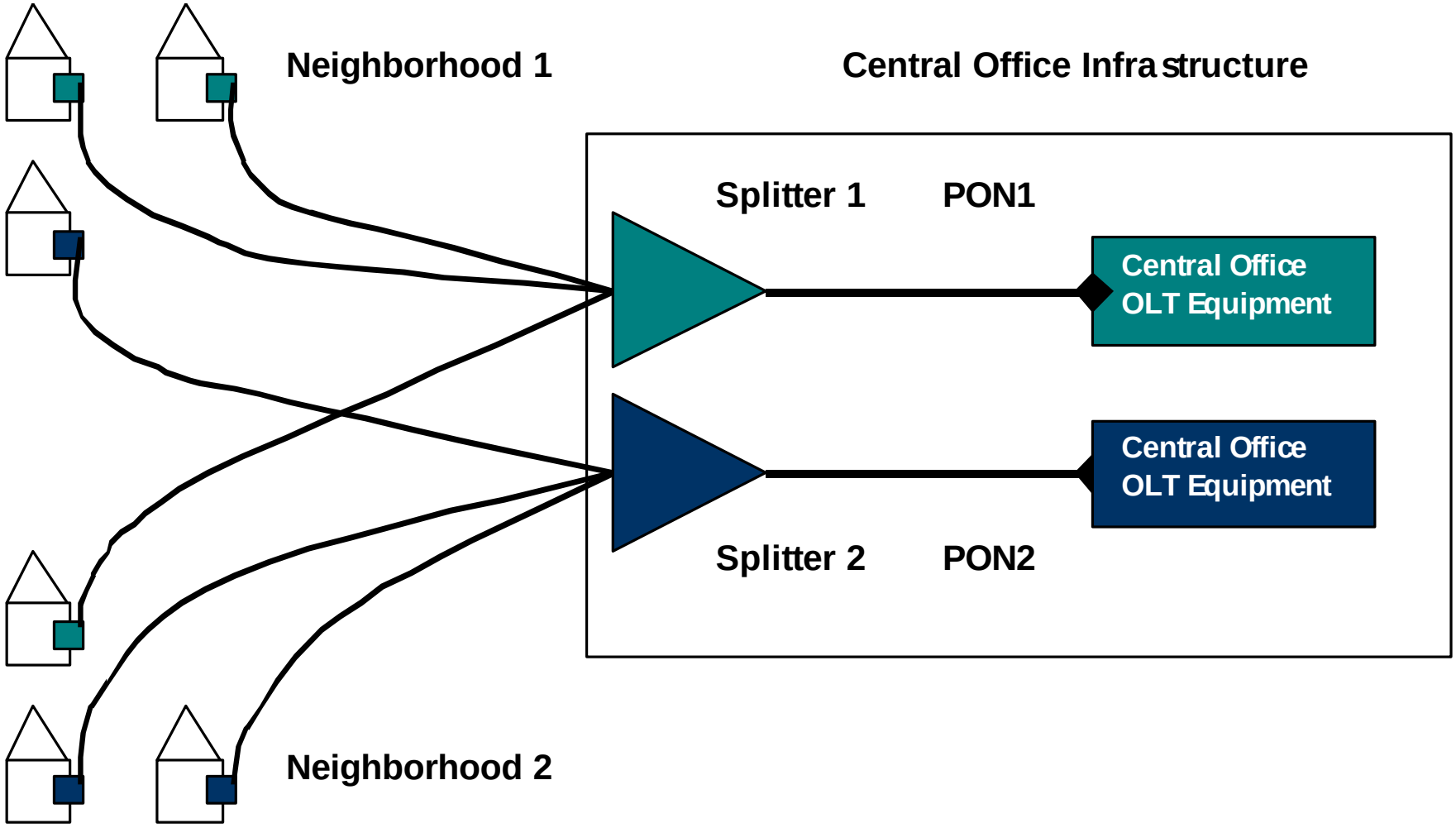
Lowering the Cost of Competition: 'Home Run PON'



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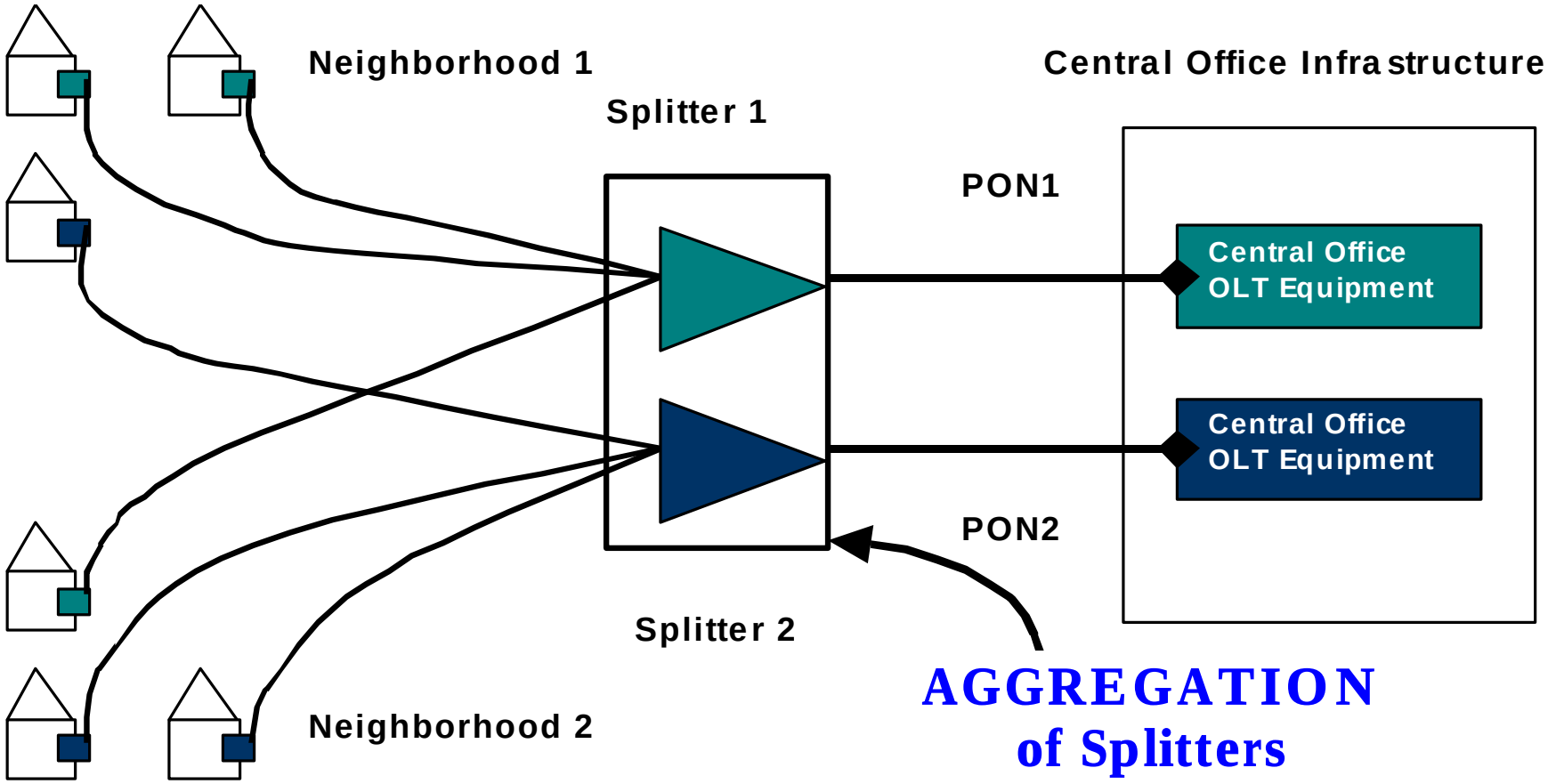
Lowering the Cost of Competition: 'Aggregation PON'



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Capital Cost premium for an architecture that enables Data-Link layer Competition

'Home Run PON' vs. Traditional PON

Deployment Scenario	Cost of Competition per Home Served (Capital Cost) ($)			Monthly Cost of Competition @ 20% discount rate ($/Month)		
	Penetration			Penetration		
	100%	65%	30%	100%	65%	30%
Urban	100	180	480	2	3	9
Suburban	180	260	670	2	4	12
Small Town	340	530	1140	6	9	19
Rural	530	730	1460	9	12	24
Remote Rural	420	660	1570	7	12	26

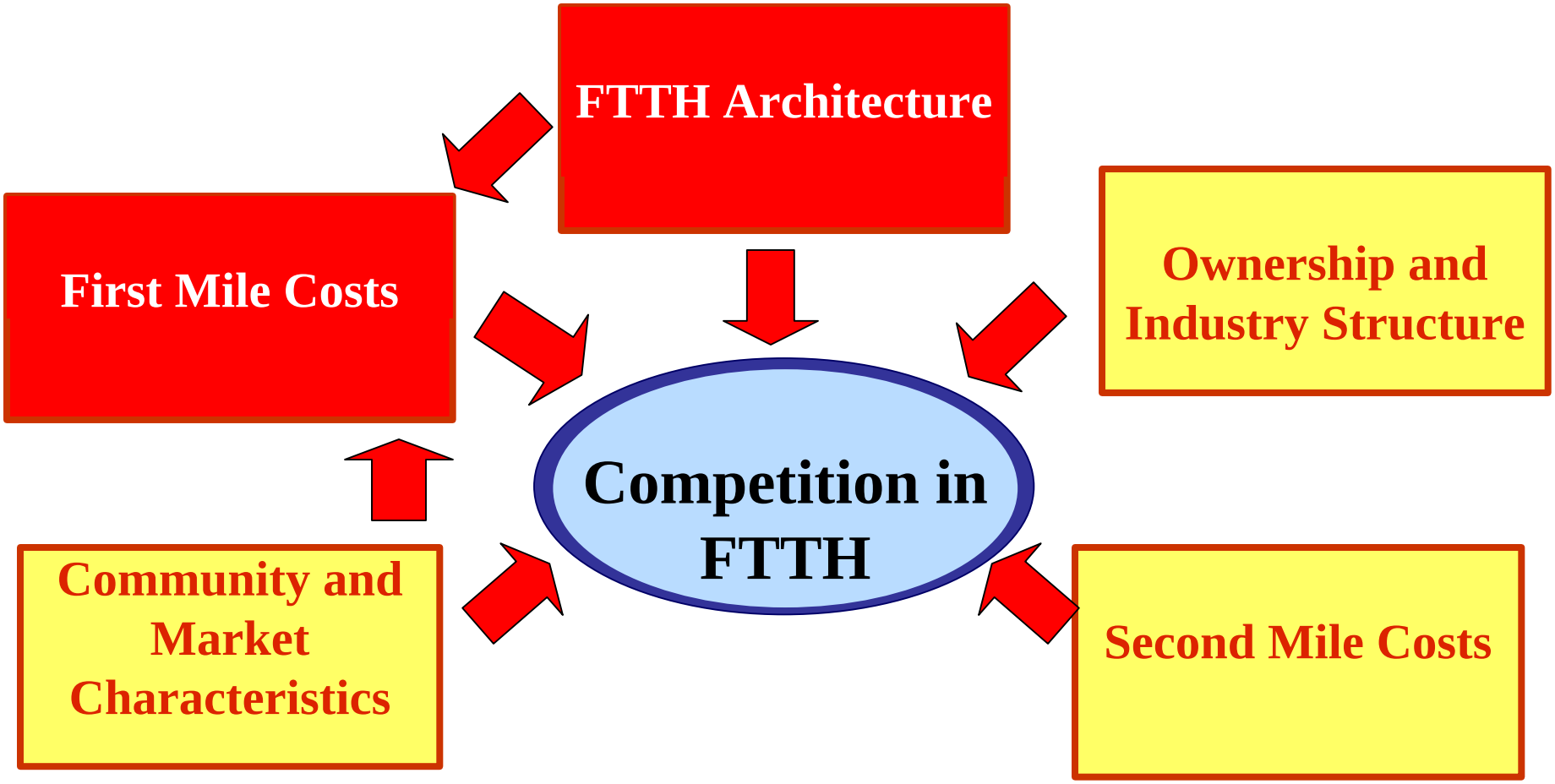
Real Option to Scale Bandwidth..

- **In addition to foreclosing competition at the Data-Link layer, PONs also impose bandwidth sharing**
- **Incremental Cost of Home Run fiber may be viewed as a Real Option to unlimited bandwidth (by scaling bandwidth independently of homes sharing a feeder fiber in a PON / Active Star)**

Is it worth paying the economic premium..

- **.. Or should we achieve a ‘Static Efficiency’ by choosing the ‘least cost’ alternative?**
- **.. And thereby foreclose a possible ‘Dynamic Efficiency’ resulting from the innovation that is driven by Competition that the Competitively Neutral architecture enables?**

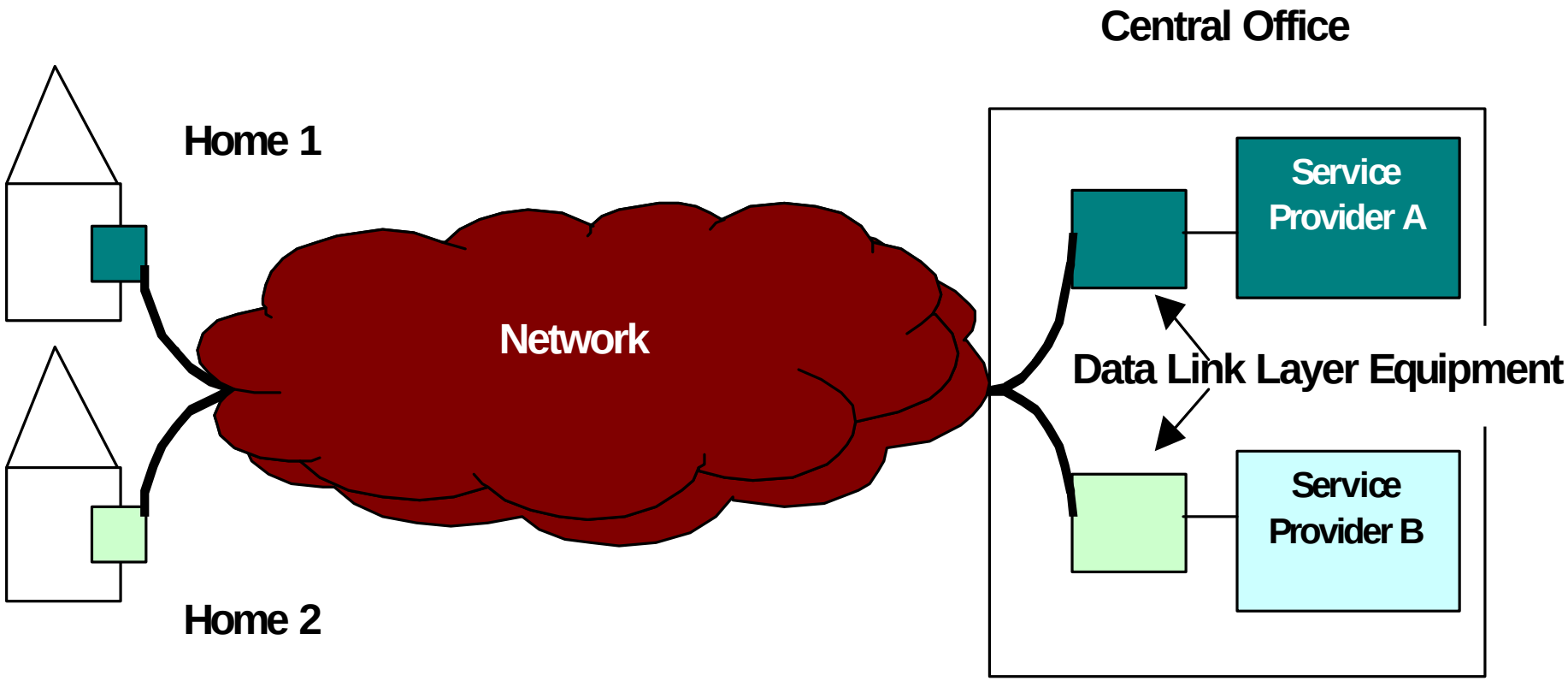
Competition in FTTH & depends on…



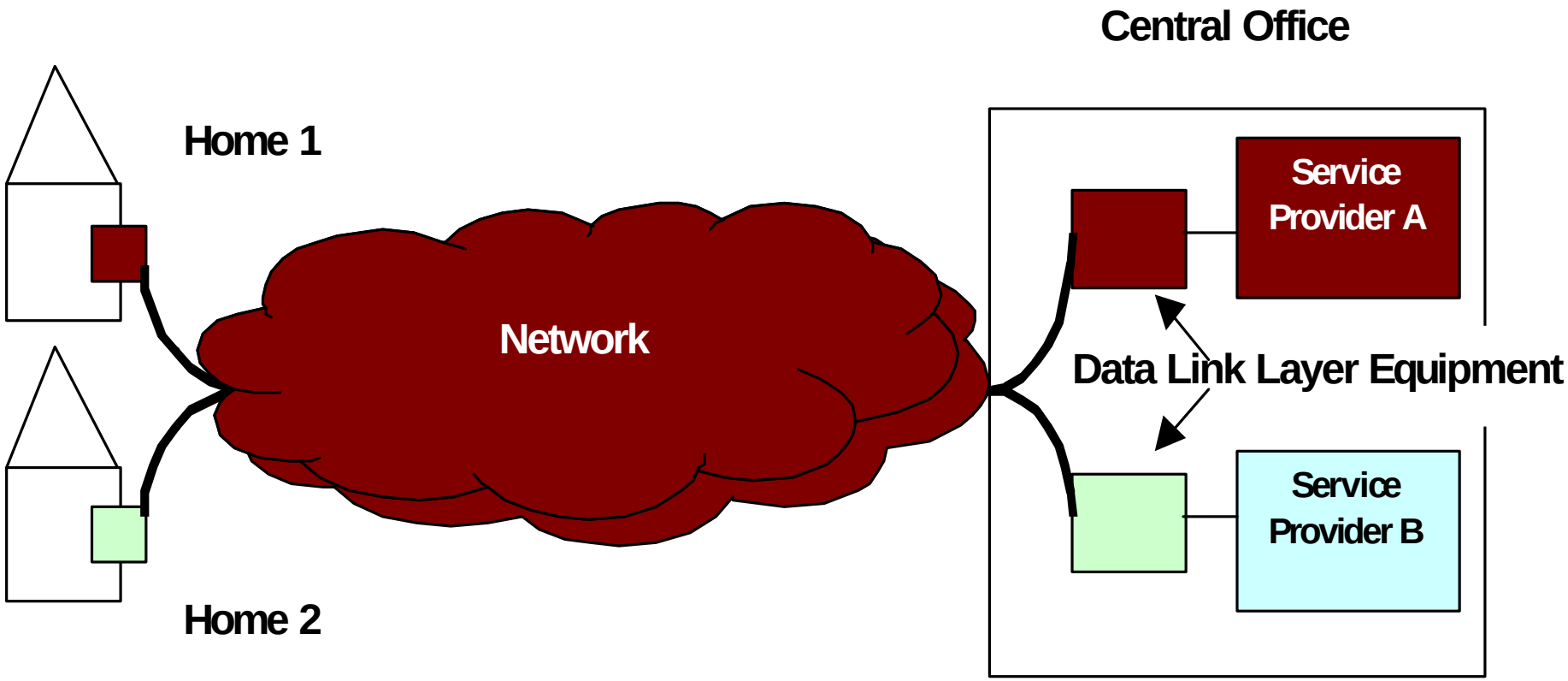
The ‘Second’ Mile Problem!!

- **The viability of competition in the last mile also depends on:**
  - The cost of bringing voice, video and data services to a Central Office (The second mile costs) from a Regional Node
  - The number of subscribers served by a Central Office
  - Distance between Central Offices
  - Demand for Services
  - ..

Non Facilities based Competition



Vertical Integration and Anti-competitive Behavior ?



Industry Structure and Competition..

- **Desired Industry Structure**
  - Neutral Infrastructure owner providing non-discriminatory access to Higher Layer Service providers
- **Ownership Alternatives**
  - Private Enterprise
  - Subscriber (or Community Ownership)
  - Local Government
  - Jointly owned common carrier
  - Power Utility
- **Migration to Desired Industry Structure?**

Conclusion..

- **PON is the most economical infrastructure**
- **Home Run Fiber is more expensive, but Competitively Neutral**
- **'Home Run PON' and 'Aggregation PON' are Competitively Neutral and Economically more Efficient than Home Run**
- **A Competitively Neutral architecture is a necessary (but not sufficient) condition for data link layer competition**

Contribution of this paper

- **Defined taxonomy of competition in FTTH**
- **Clarified relation of architecture to Data Link layer competition**
- **Understood the economics of FTTH architectures in different deployment scenarios**
- **Estimated "Cost of Data-Link layer Competition"**
- **Devised compromise architectures to enable competition at lower first capital cost**
- **Identified institutional and economic issues for further study**

.. and Future Work

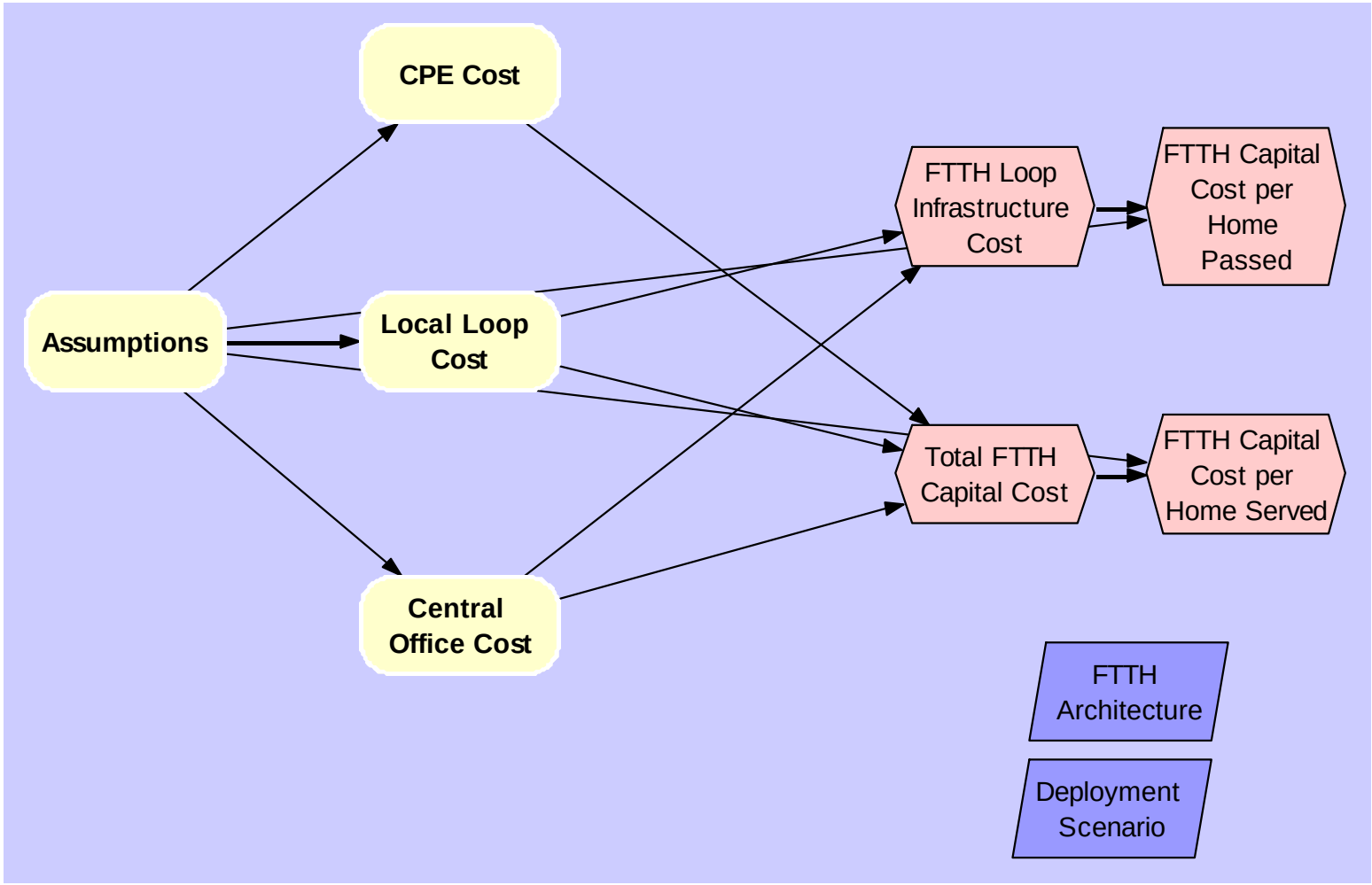
- **Continue to explore implications for Competition of:**
  - **Second Mile Costs**
  - **Ownership options**
  - **Operations Costs**
  - **Market Characteristics**

Engineering Cost Model Assumptions and Results

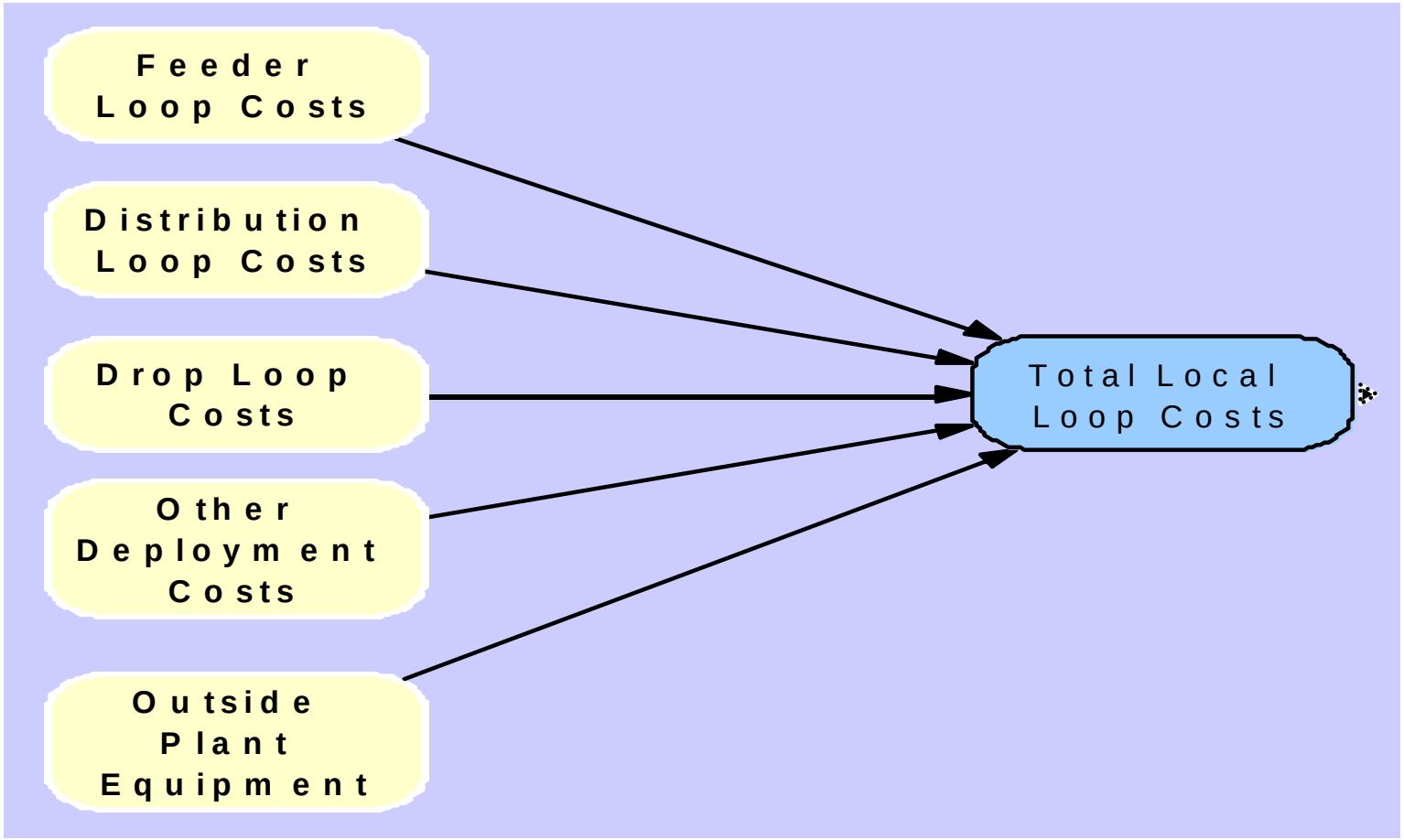
Engineering Cost Model

- **Estimates Capital Cost per Home Passed and Capital Cost per Home Served for FOUR architectures and FIVE deployment contexts**
- **Aerial Fiber deployed on poles**
- **Sufficient Feeder and Distribution fiber for the entire community installed regardless of the number homes that sign up for service**

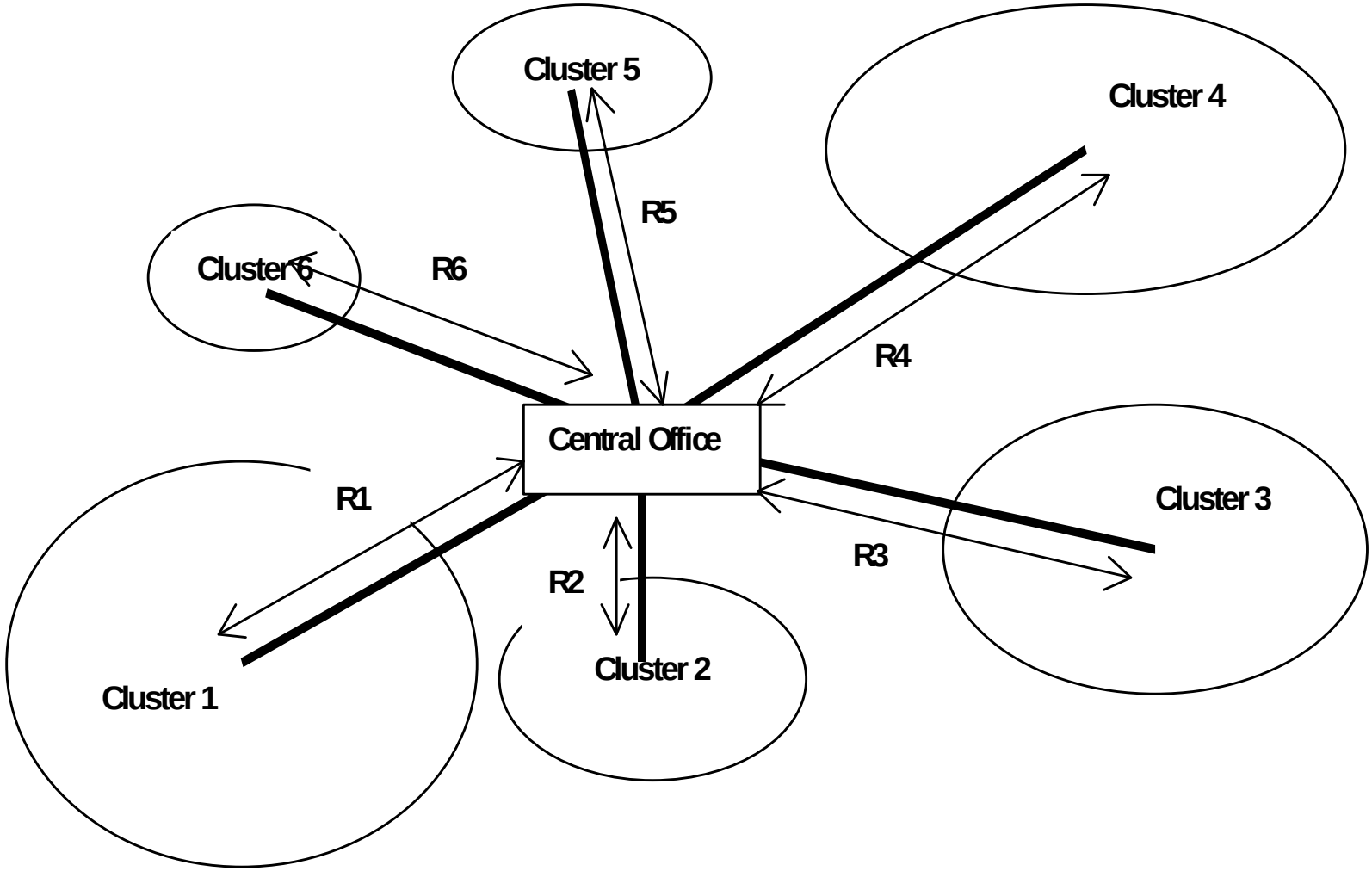
Cost Model


CPE Cost
Assumptions
Local Loop Cost
Central Office Cost
FTTH Loop Infrastructure Cost
Total FTTH Capital Cost
FTTH Capital Cost per Home Passed
FTTH Capital Cost per Home Served
FTTH Architecture
Deployment Scenario

Local Loop Costs



Data from HAI Model 5.0 A



Data from HAI Model 5.0 A

Central Office (CLLI)	No. of Clusters	Total no. of Homes	Housing Density (Homes/sq. mi.)	Average Radial Distance from CO to each cluster (ft)
PITBPASQ (Urban)	23	16,135	3,389	4,730
HMSTPAHO (Suburban)	23	16,201	1,603	9,089
CHTTPACT (Small Town)	14	10,184	218	15,165
TNVLPATA (Rural)	10	5,871	86	18,662
CCHRPAXC (Remote Rural)	18	3,018	20	32,763

Cost Model Assumptions

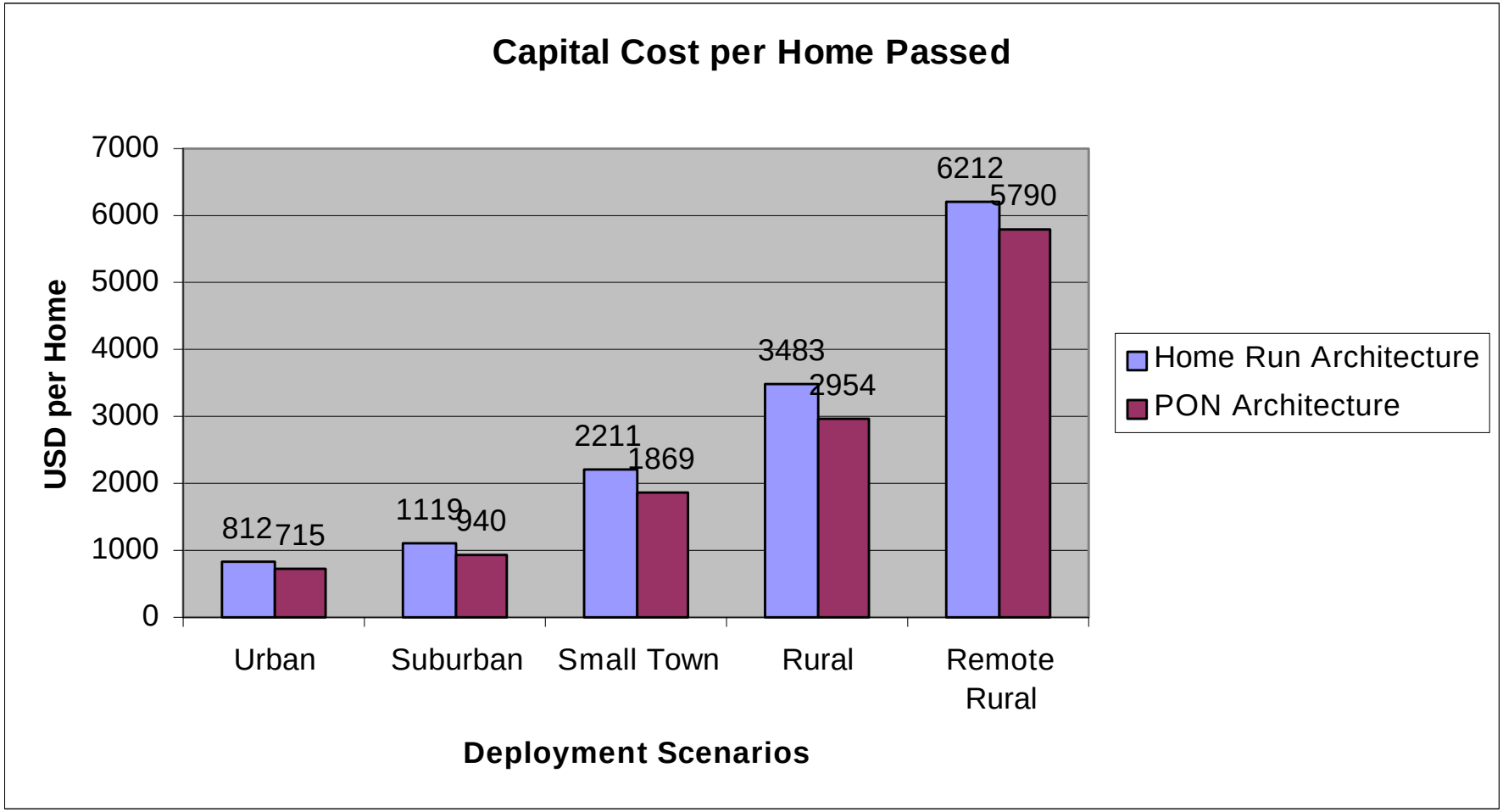
Deployment	Homes per sq. mile	Homes served per CO	Ave. Feeder Loop length (feet)	Average Distribution Loop length	Drop Loop length
Urban	3389	16,135	6,960	377	Uniform(50,75)
Suburban	1602	16,201	12,396	521	Uniform(75,150)
Small Town	217	10,184	24,012	1,472	Uniform(100,200)
Rural	85	5,871	37,054	2,434	Uniform(150,300)
Remote Rural	20	3,018	42,084	5,791	Uniform(200,600)

Equipment and Costs

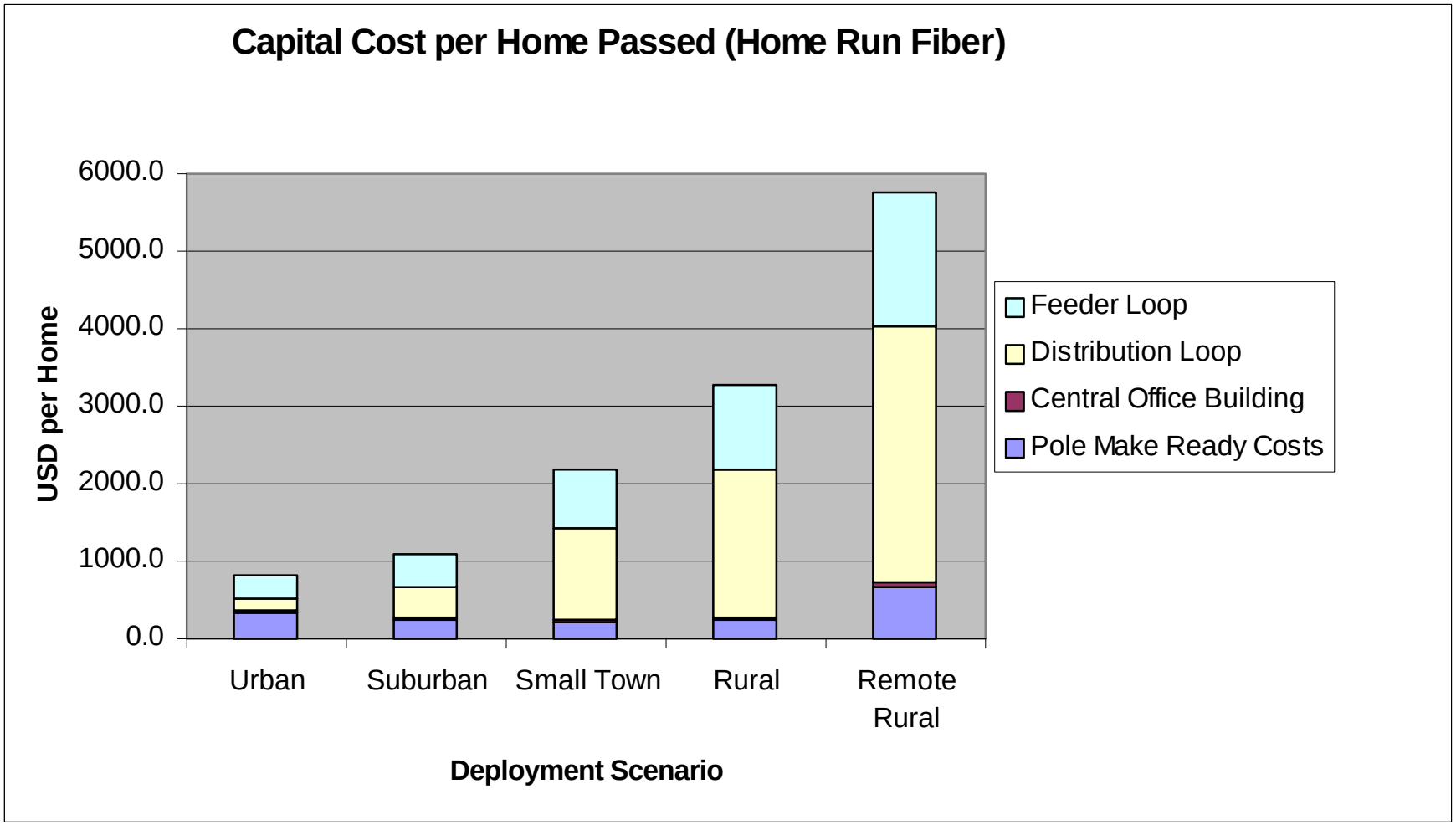
Architecture	OLT Interface	ONU Interface
Home Run	100 Mbps Fast Ethernet per Home	2 POTS, 10/100 Base T, RF Video
Active Star	Gigabit Ethernet Interface per 32 Homes	2 POTS, 10/100 Base T, RF Video
PON	Gigabit Ethernet Interface per 32 Homes	2 POTS, 10/100 Base T, RF Video
WDM PON	100 Mbps Fast Ethernet per Home	2 POTS, 10/100 Base T, RF Video

Architecture	Central Office Equipment (per 32 Homes)	Central Office Equipment (per Home)	Optical Network Unit (ONU)	Remote Node Equipment (per Home)
Home Run		$375	$550	
Active Star	$800	$25	$550	$250
PONs	$2,375	$75	$650	$25
WDM PON		$20,000	$1,500	$25

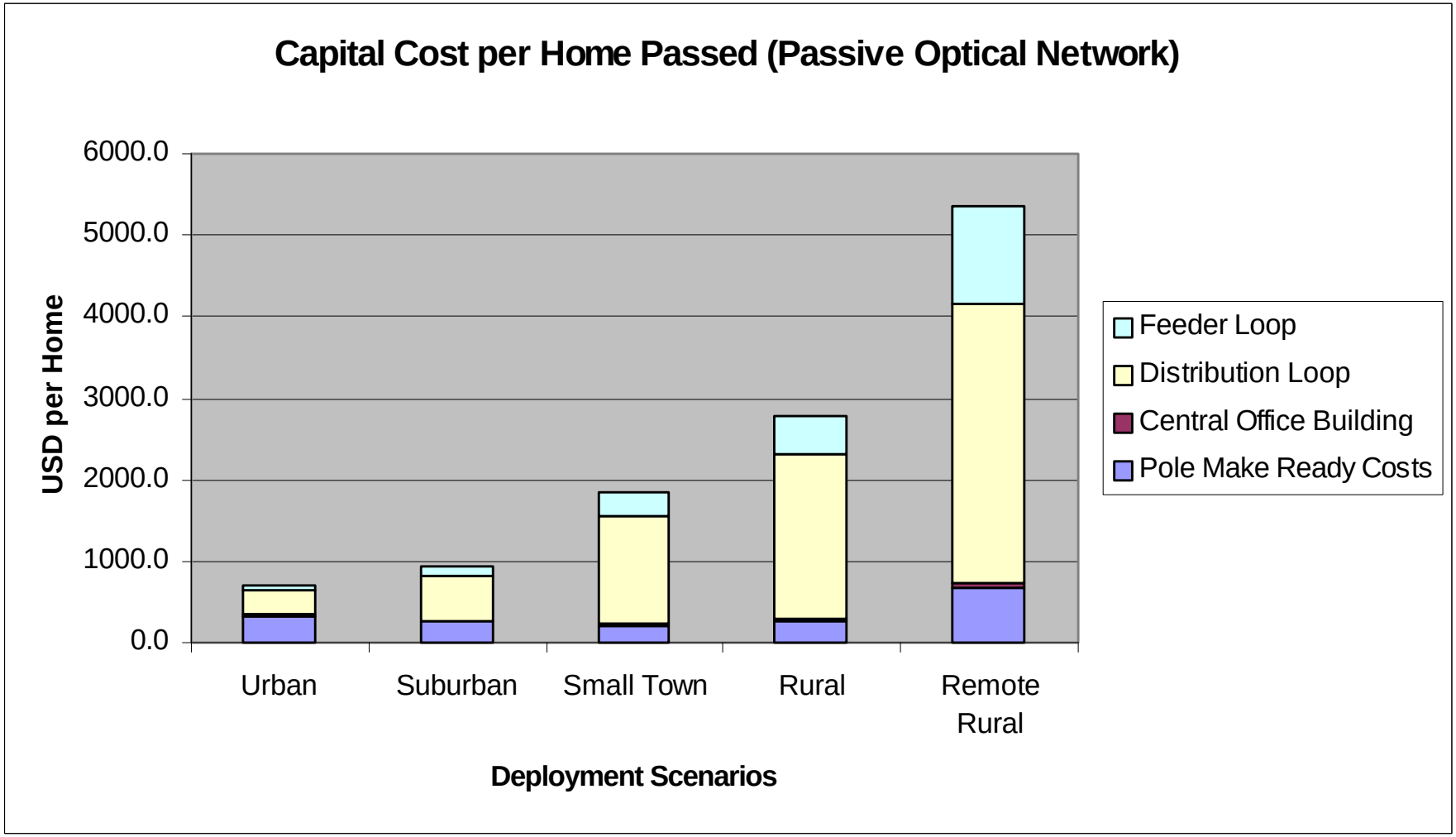
Capital Cost per Home Passed



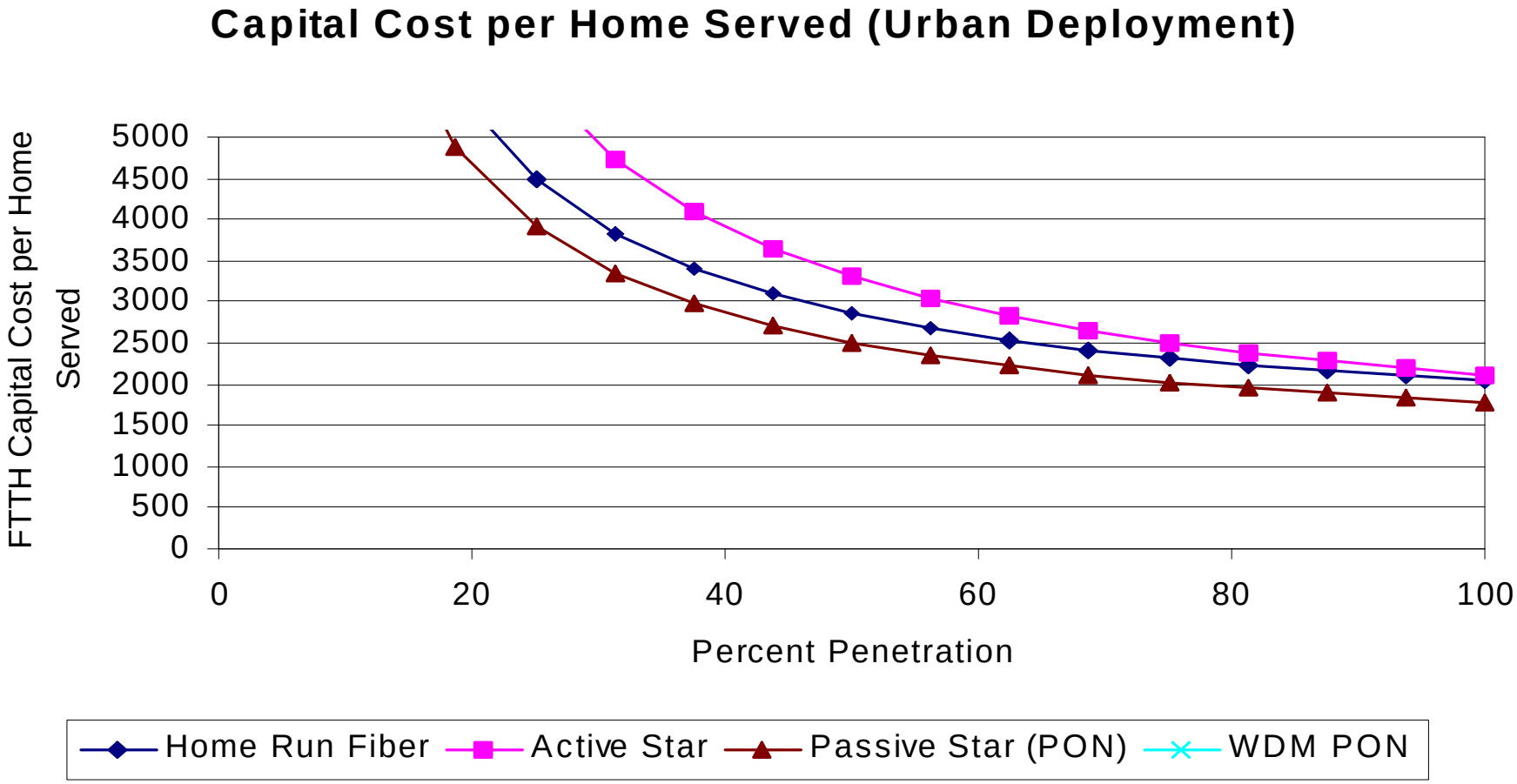
Fiber Loop Cost Breakdown (Home Run Fiber)



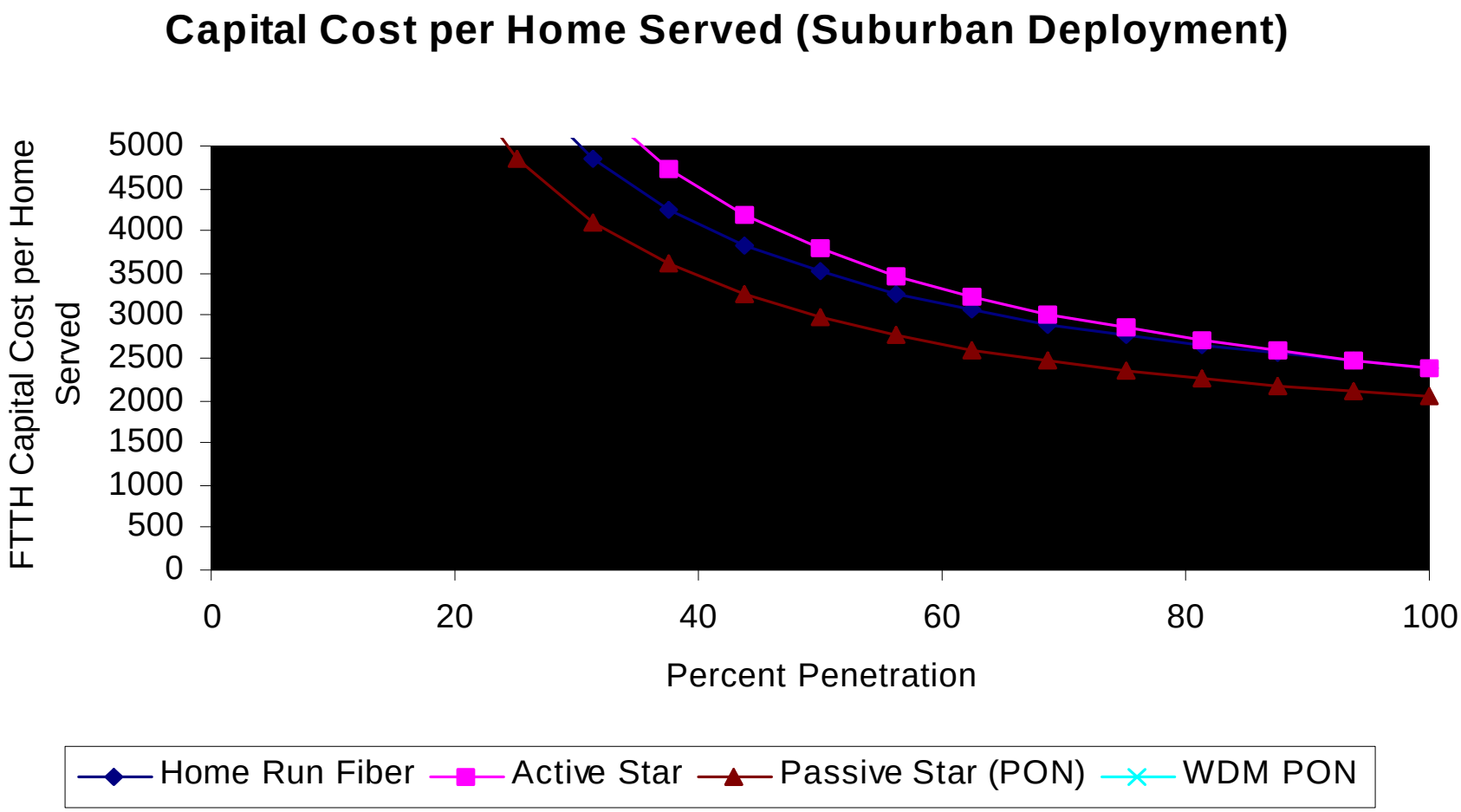
Fiber Loop Cost Breakdown (PON)



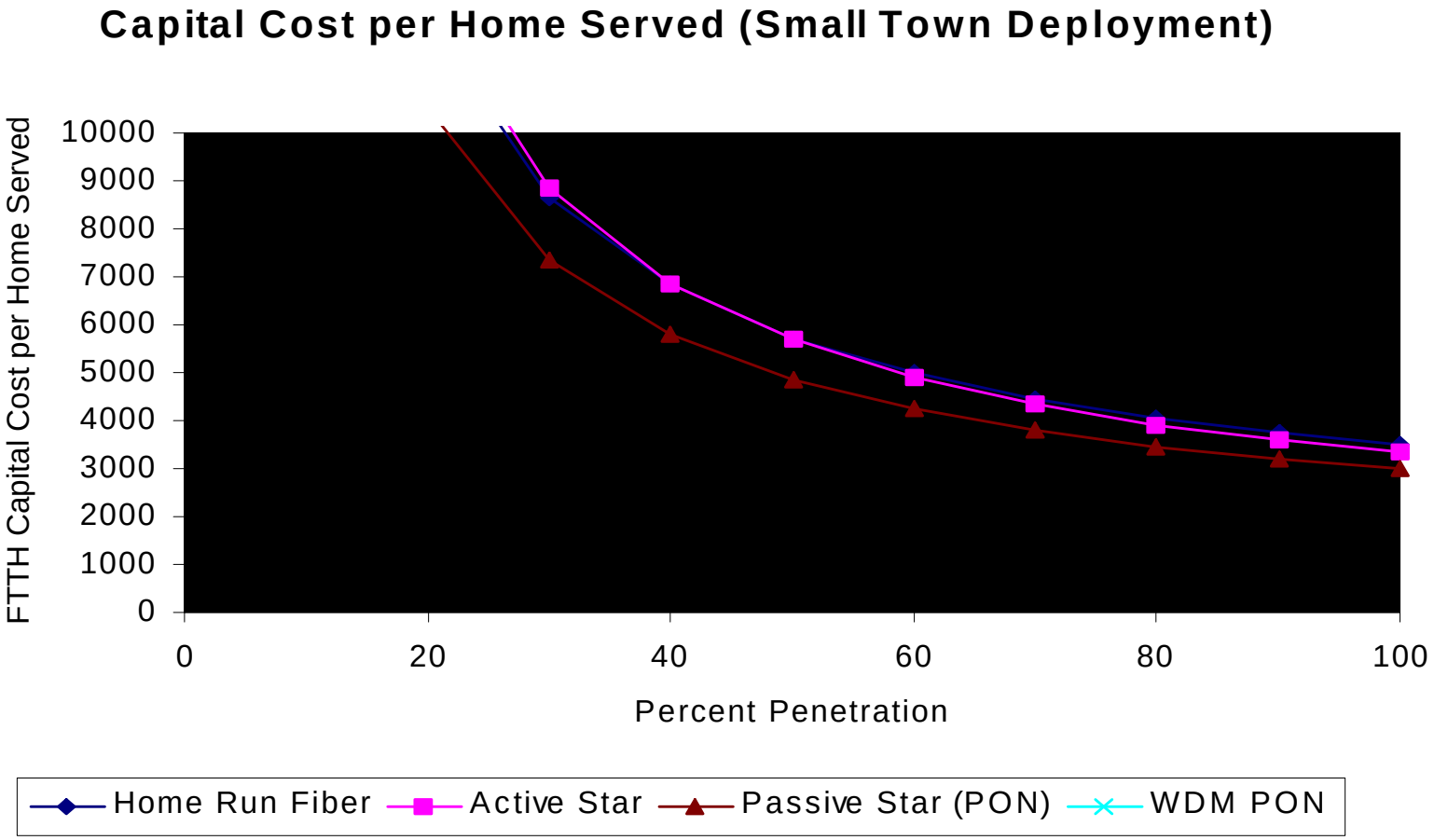
Capital Cost per Home Served (Urban Deployment)



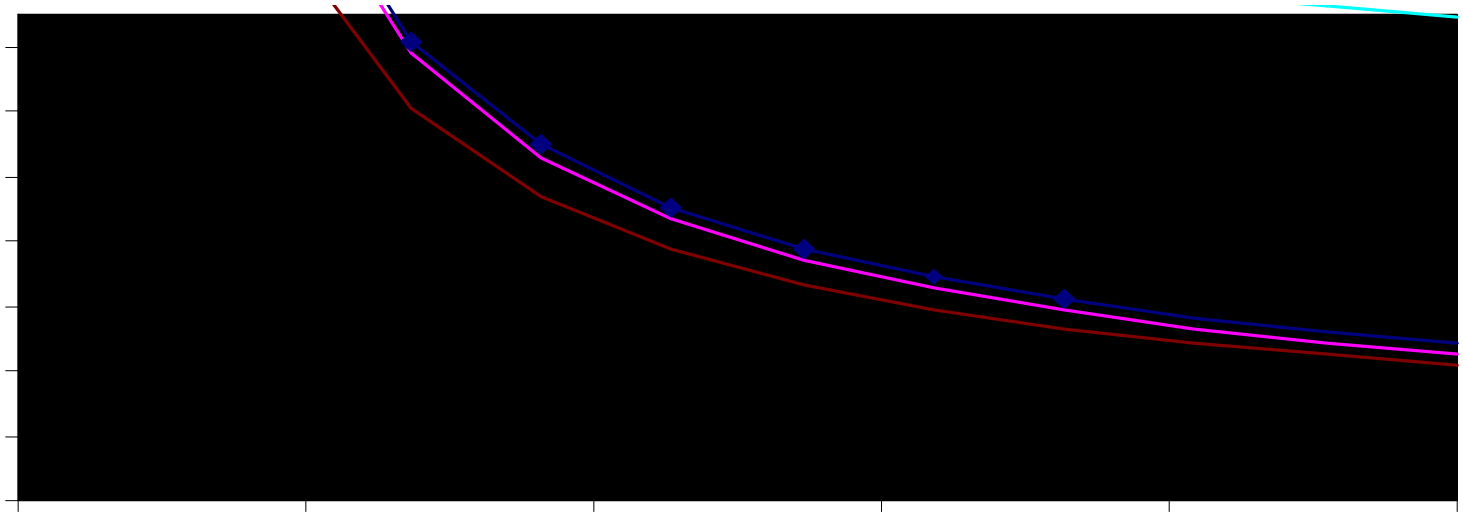
Capital Cost per Home Served (Suburban Deployment)



Capital Cost per Home Served (Small Town Deployment)



Capital Cost per Home Served (Rural Deployment)



Capital Cost per Home Served (Remote Rural Deployment)