A Novel Approach for the Definition of the 5G Use Cases and their Deployment Requirements

5G-PHOS: 5G integrated Fiber-Wireless networks exploiting existing photonic technologies for high-density SDN-programmable network architectures

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5G-PHOS in Brief

- **5GPP Phase 2 Project, September 2017-August 2020**

The key focal points are to:

- architect and evaluate 5G broadband networks for the identified 5G use cases
- capitalize on existing wireless and optical technologies, migrating from CPRI - based towards integrated Fiber-Wireless (Fi Wi) fronthaul/backhaul supporting mmWave mMIMO communications
- support the telecom demands of all the potential stakeholders (subscribers/individuals, fans, tenants/verticals, infrastructure owners, etc.)
- address the strict quality of service requirements of 5G services

Use Cases and the Challenge

- 3 Areas of Use Cases are identified in 5G-PHOS :
  - ✓ Dense
  - ✓ Ultra Dense
  - ✓ Hotspot
- BUT:
  - ✓ it is hard to find an analytic study of what 5G means in terms of real deployments
  - ✓ variations and even conflicts can be found in the literature regarding the approximation of services, areas usage scenarios
    - the population (/traffic density) in a stadium can vary from 10-100.000
    - urban areas have different characteristics even in the same country, not to mention in different continents e.g. Europe and Asia.

Such generalities can significantly affect
case comprehension and traffic predictions
in a yet unknown 5G ecosystem

5G-PHOS Approach & Methodology

- Step 1: Identification and description of the 5G services/ applications
  - ✓ along with their QoS characteristics to be made available in the area under study
- Step 2: Selection of a wide (dense) urban real geographical area that:
  - ✓ exhibits high population/subscribers and/or (Internet of Things (IoT)) devices
  - ✓ includes touristic locations
  - ✓ contains hotspots, open areas/parks where massive gatherings take place
- Step 3: Calculation of the traffic density for a range of scenarios/events considering
  - ✓ low/high daily traffic, based on specific events, etc.,
  - ✓ the number of potential subscribers/devices and
  - ✓ the usage of concurrent 5G services
- Step 4: Design the 5G-PHOS solution(s) to address
  - ✓ the traffic demands and QoS needs for the specific scenario/ event
  - ✓ the area characteristics
  - ✓ potential restrictions (regulatory issues, fiber unavailability, etc.).

5G-PHOS Traffic Calculation Tool

- To aid Step 3 for Traffic Calculations, a general purpose tool has been developed:
  - ✓ for each Usage Scenario (“Event”) taking into account
    - the area characteristics (Km^2, perimeter, population, density)
    - the usage characteristics (devices, subscribers density, concurrent use of 5G Services)
    - the involved 5G Services categories and concurrency among them
  - ✓ and Calculates
    - the total traffic generated for the specific event (#subs + service usage, #tenants)
    - the latency requirements that need to be met (min, max) [per service, slice]
    - the min traffic demands to be supported based on the services’ “criticality”.

Application in 5G-PHOS Realistic Scenarios

Step 1: Identification of 5G-Services/Applications/QoS

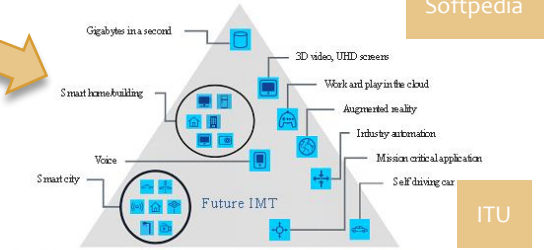
- eMBB
- mMTC
- URLLC
- NOS

5G-Services

5G-Apps

- Versatile in terms of functionality
- Large number of technical & market reports

Softpedia



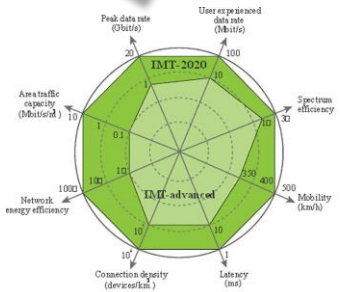
ITU

5G-Verticals

- Automotive
- eHealth
- Energy
- Media & Entertainment
- Factories of the Future

QoS

- Mobility
- Latency
- Density
- Energy Efficiency
- Traffic Capacity
- Bandwidth



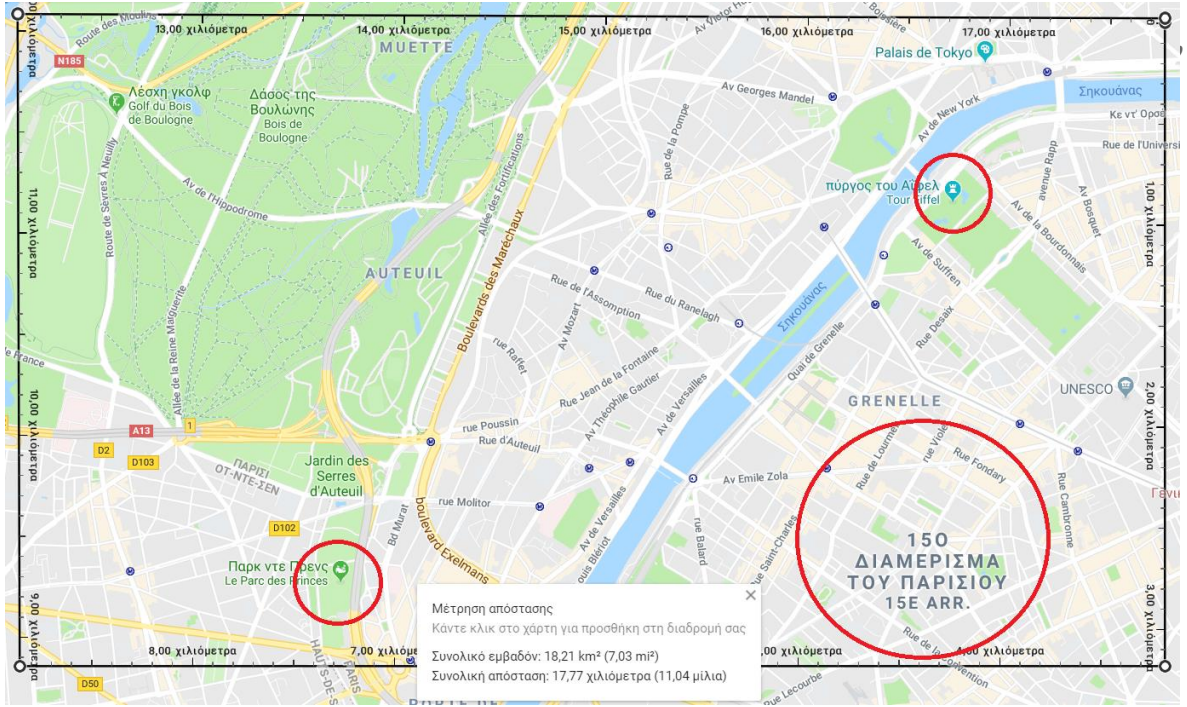
IMT

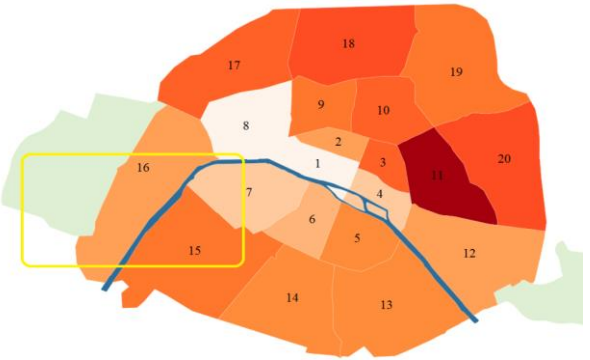
	IMT-Advanced	IMT-2020
Mobility	350 km/h	500 km/h
User Plane Latency	10 msec	1 msec[21]
Connection Density	100 thousand devices/sq.km.	1 million devices sq./km.
Network Energy Efficiency	1 (normalized)	100X over IMT-Advanced
Area Traffic Capacity	0.1 Mbps/sq. m.	10 Mbps/sq. m. (hot spots)
Bandwidth	Up to 20 MHz/radio channel (up to 100 MHz aggregated)	Up to 1 GHz (single or multipole RF carriers)

Application in 5G-PHOS Realistic Scenarios

Step 2: Selection of a wide (dense) urban real geographical area

- Urban Area in Paris, France





A wide range of «environments», exhibiting different characteristics in terms of: population/subscribers' densities and service usage, both under normal conditions and on specific events.

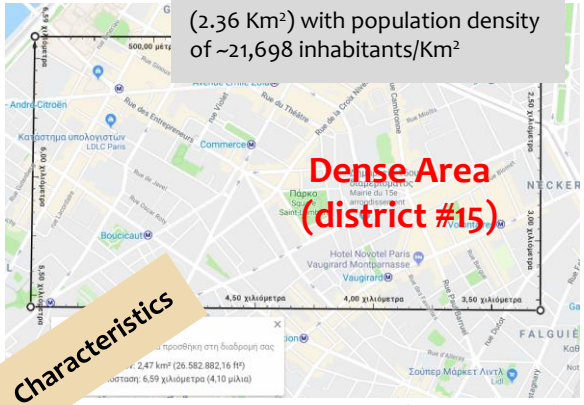
Satellite Image (3D): https://www.google.gr/maps/@48.8152954,2.2592939,2285a,35y,16.17h,53.95t/data=!3m1!1e3?hl=el

Application in 5G-PHOS Realistic Scenarios

Step 2: Selection of real geographical area: Points of Interest , Usage Scenarios

Use case 1: Dense Area

(2.36 Km²) with population density of ~21,698 inhabitants/Km²



Characteristics

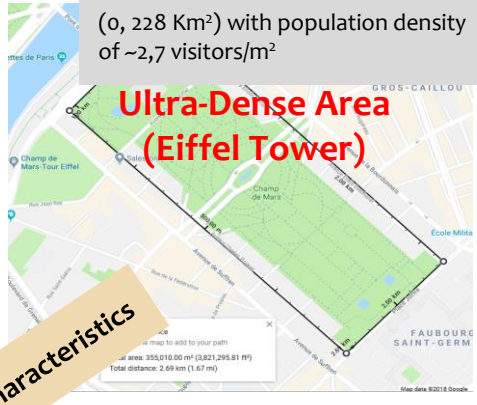
High demands generated during busy/ working hours for homes and businesses
- High mobility demands during the rush hour (e.g. 08:00-09:00 am)
- Smart city services and smart vertical services
- Emergency situations and critical mIoT

Services → (UC1: Rush Hours) (UC2: Normal Daily) (UC3: Night Hours)

- Low-bandwidth services
- High capacity eMBB services
- mMTC services
- URLLC services
- Other services

Use case 2: Ultra-Dense Area

(0, 228 Km²) with population density of ~2,7 visitors/m²



Characteristics

- Extreme traffic densities when big events (e.g. open-air concert, national celebration) take place
- Normal (daily) traffic based on 5G services' usage by the tourists and/or employees

Services → (UC1: Normal Daily) (UC2: Big Events)

- Low-bandwidth and non time-critical services
- High capacity eMBB services

Use case 3: Hotspot

(7200 m² field size) with population of 48527 spectators

Characteristics

- Extremely high (traffic) demands during an event
- significantly lower daily traffic demand, generated by stadium employees

Services → (UC1: Big Events) (UC2: Normal Daily)

- Low-bandwidth and non time-critical services
- High capacity eMBB services

Application in 5G-PHOS Realistic Scenarios

Step 3: Calculate Traffic per Use Case

	Provided Services	Data Rates		Activity factor	Traffic			Latency	Criticality	Indicative Services
		DL (Mbps)	UL (Mbps)	% Usage	DL (Gbps)	UL (Gbps)	Total (Gbps)			
3G/4G services	Phone Calls	0,03	0,03	20%	0,3	0,3	0,5	10 ms	Medium	
	Non-critical/Non-demanding data services	0,025	0,025	10%	0,1	0,1	0,2	50 ms<	Low	On-line bidding, contests, IP-messaging, push notifications. etc.
	High Speed Broadband Services	10	10	3%	13	13	26,4	2-4ms:50 ms	Medium	Video, email, web surfing (latency of 50ms<), interactive video (2-4ms latency), etc.
mMTC	Massive low-cost/long-range/low-power MTC	0	0,025	5%	0,00	0,1	0,1	10 ms - few se	Medium - High	Massive IoT services for asset tracking (tickets, goods, etc.), energy management (incl. lights, sound, heating/cooling, etc.), control services (incl. security devices, presence sensors), etc.
eMBB	Broadband Access in a Crowd	25	50	5%	55	110	165,1	10 ms	Low	(HD) video / photo sharing
	Broadcast like services	200		5	1		1,0	< 100 ms	Low	4K/8K video watching
			0,5	5%		1	1,0	< 100 ms	Low	

	Slicing Services for Tenants	Min (Gbps)	Max (Gbps)	#Tenants	Min (Gbps)	Max (Gbps)	Average (Gbps)	Latency	Criticality	Indicative Services
eMBB	Slice for Broadcast like services	3	10	3	9	30	19,5	< 100 ms		TV/radio broadcasting & other communication services
	Slice for Stadium Operator	3	10	1	3	10	6,5	1 ms - few sec	High	Surveillance/security services (UHD/AR monitoring), Replays on a big screen inside the stadium
UR-LLC	Reserved Slice for Emergency	3	10	1	3	10	6,5	1 ms - few sec	High	Emergency services / first responders

	UL	DL	Total Average	Total Max
Totals (Gbps)	85,9	141,0	226,9	244,4
Absolute min (Gbps)	20,0			
Latency	1 - 100 ms			

based on High critical services (max Gbps)

Indicative Calculations for **Hotspot: "Big Event" Scenario**

Results: 5G-PHOS Traffic Requirements

Dense Urban Area – Rush Hours	
Total maximum Capacity	~396 Gbps (absolute minimum 21 Gbps)
Average Capacity	385 Gbps
Latency	1-100 ms depending on service
Traffic Density	~0.1625 Mbps/m²
Connection Density	~0.0318 connections/m²

Dense Urban Area – Normal Daily	
Total maximum Capacity	~1450 Gbps (absolute minimum 21Gbps)
Average Capacity	1430 Gbps
Latency	1-100 ms depending on service
Traffic Density	~0.06 Mbps/m²
Connection Density	~0.0036 connections/m²

Dense Urban Area – Night Hours	
Total maximum Capacity	~120 Gbps (absolute minimum 21Gbps)
Average Capacity	105,9 Gbps
Latency	1-100 ms depending on service
Traffic Density	~0.045 Mbps/m²
Connection Density	~0.03 connections/m²

Ultra Dense Area – Normal Daily	
Total maximum Capacity	~234 Gbps (absolute minimum 22 Gbps)
Average Capacity	223 Gbps
Latency	1-100 ms depending on service
Traffic Density	~0.67 Mbps/m²
Connection Density	~0.01 connections/m²

Ultra Dense Area – Big Event	
Total maximum Capacity	~2700 Gbps (absolute minimum 22 Gbps)
Average Capacity	2686.4 Gbps
Latency	1-100 ms depending on service
Traffic Density	~11.8 Mbps/m²
Connection Density	~0.8 connections/m²

Hotspot – Big Event	
Aggregate Max. Capacity	~250 Gbps (for an area ~0,018 Km²)
Absolute Min. Capacity	20 Gbps reserved for emergency services due to their high criticality
Latency	1-100 ms
Traffic Density	~12 Mbps/m²
Population Density	2.65 people/m² and 2.38 subscribers/m²
Connection Density	max 1.2 connections/m²

Hotspot – Normal Daily	
Aggregate Max. Capacity	~25 Gbps (for an area ~0,16 Km²)
Absolute Min. Capacity	13 Gbps reserved for emergency services due to their high criticality
Latency	1-100 ms
Traffic Density	~0.1 Mbps/m²
Population Density	0.0018 subscribers/m²
Connection Density	max 0.02 connections/m²

Results: 5G-PHOS Performance Targets

- 5G-PHOS vs. IMT-2020 End User Performance Targets

End User Performance Targets	5G-PHOS UC Targets	IMT-2020 Targets
Min. Latency	1 ms	1 ms
Max. Traffic Density	~12 Mbps/m^2	10 Mbps/m^2
Max. Connection Density	~1.2 connections/m^2	1 connections/m^2
Max. Mobility	100 Km/h	500 Km/h
Max. User Experienced Data Rate	75 Mbps	100 Mbps

per FlexBox

(a) DN = **25 Gb/s**

(b) UDN = **400 Gb/s**

(c) Hotspot = **100 Gb/s**

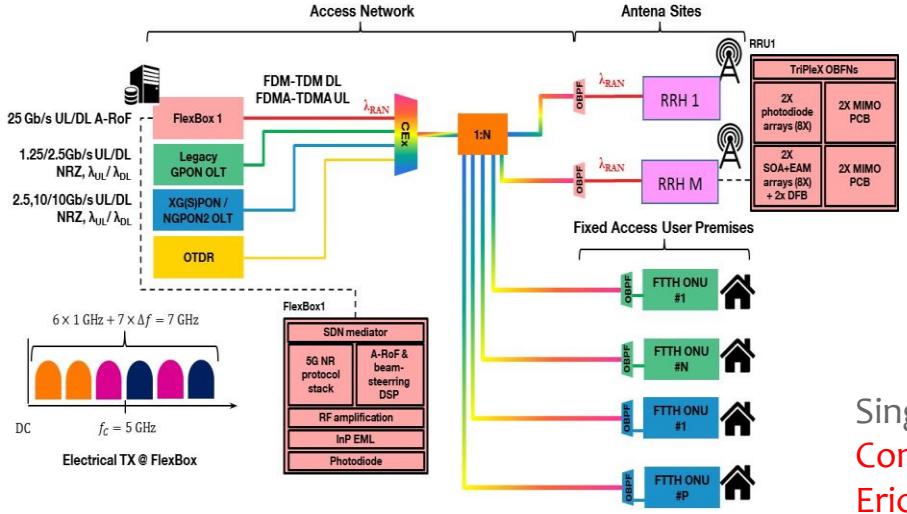
Energy vs. 4G: **4x** (DN), **18x** (UDN), **13x** (Hotspot)

Latency: <5ms (DN) and **<1ms** (UDN, Hotspot)

Results: Target Network Architecture (1)

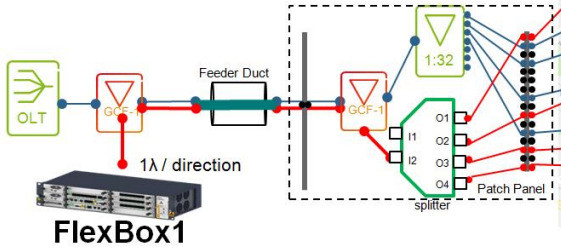
Step 4: Design the 5G-PHOS solution(s)

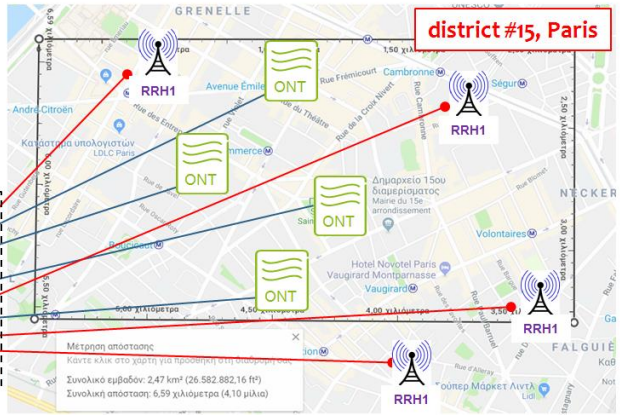
- Dense Area Urban Use Case: Proposed Network Design



Single λ @1535-1540

Compatibility with Ericsson & TIM

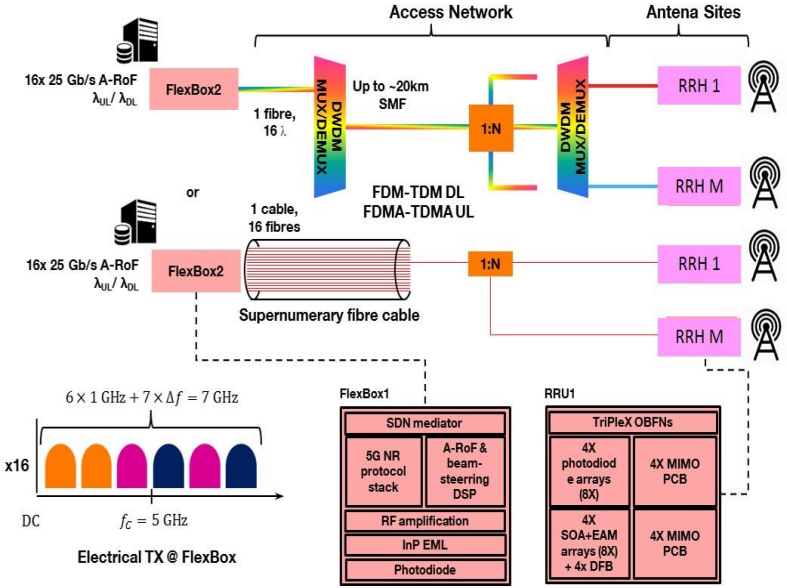




Results: Target Network Architecture (2)

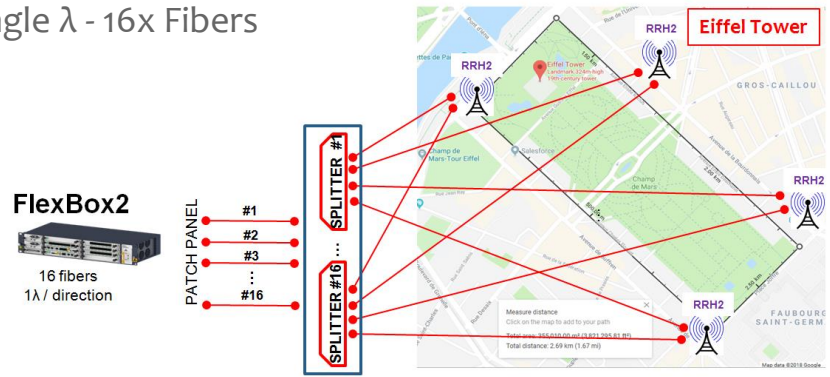
Step 4: Design the 5G-PHOS solution(s)

- Ultra-Dense Area UC: Proposed Network Design



SDM (new architecture)

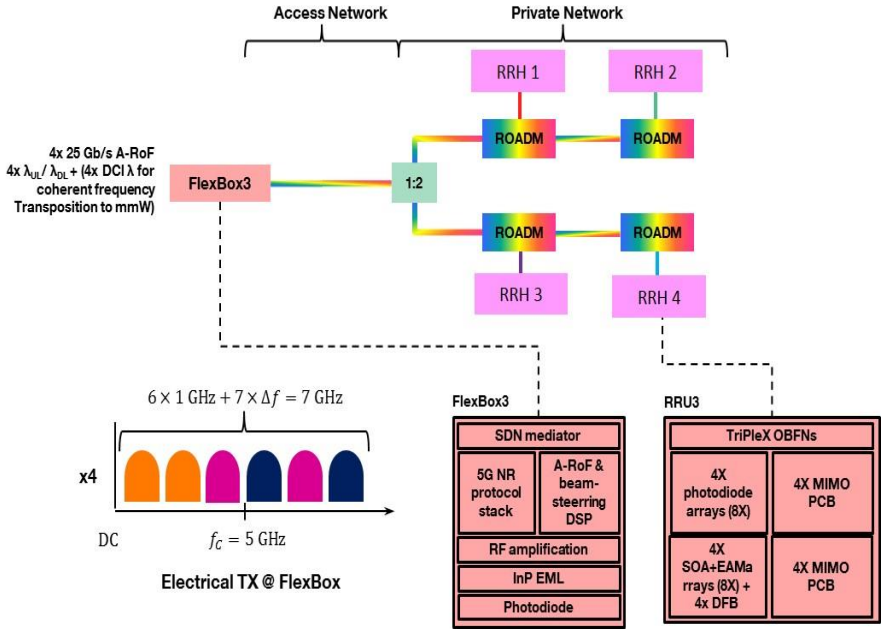
Single λ - 16x Fibers

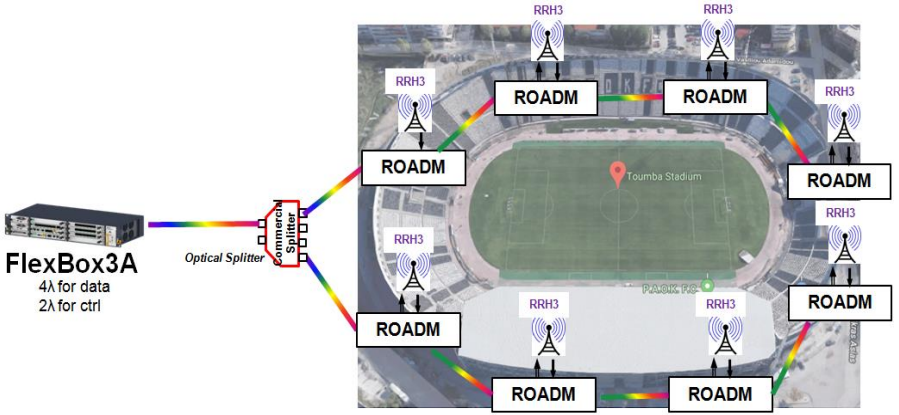


Results: Target Network Architecture (3)

Step 4: Design the 5G-PHOS solution(s)

- Hotspot UC: Proposed Network Design





WDM capabilities

Multi-λ – Bus

ROADM Reconfig

THANK YOU!