New KPIs For Planning Microwave And Millimeter-wave Backhaul Networks

Presented by: **Name (Company), Role**

Place Date

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Organization and work

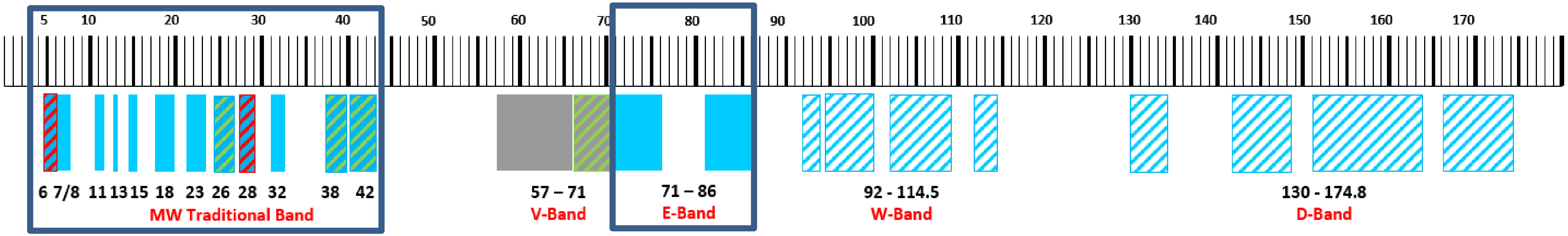
Officials - mWT

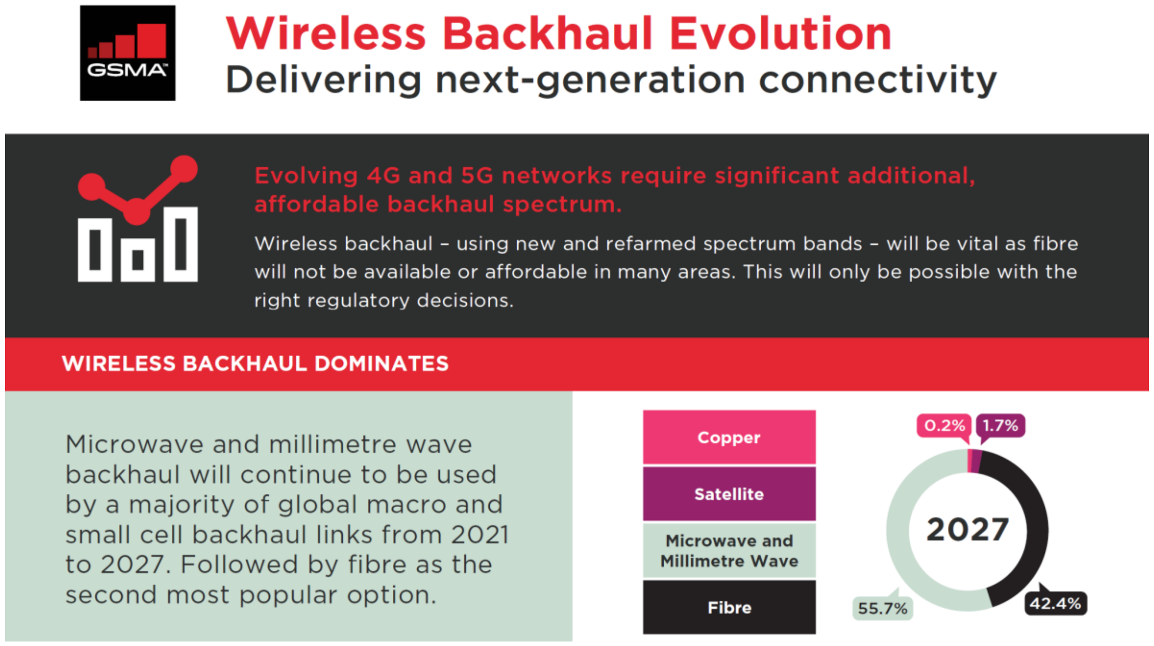
4 person(s) found

Name	Role	Organization
Lombardi Renato	Chairman	Huawei Tech.(UK) Co.. Ltd
Zein Nader	Vice Chairman	NEC Europe Ltd
Zein Nader	Secretary	NEC Europe Ltd
Mouquet Antoine	Technical Officer	ETSI

- Very simple and lean organization without further sub-groups
- Organized by activities with formal Work Items for which Rapporteur is defined together with supporting companies (standard ETSI procedure)
- Around twenty companies with stable and active participation
  - Vendors **Huawei, Nokia, Ericsson, NEC**, SIAE, Ceragon,
  - Operator **DT**, **Vodafone**, TIM, BT
  - Antenna Huber+Suhner, **Commscope**, RFS (Nokia)
  - Semiconductor **Infineon**, ST Microelectronics, IMEC, Filtronic, Maxlinear

Role of wireless backhaul in Mobile Networks





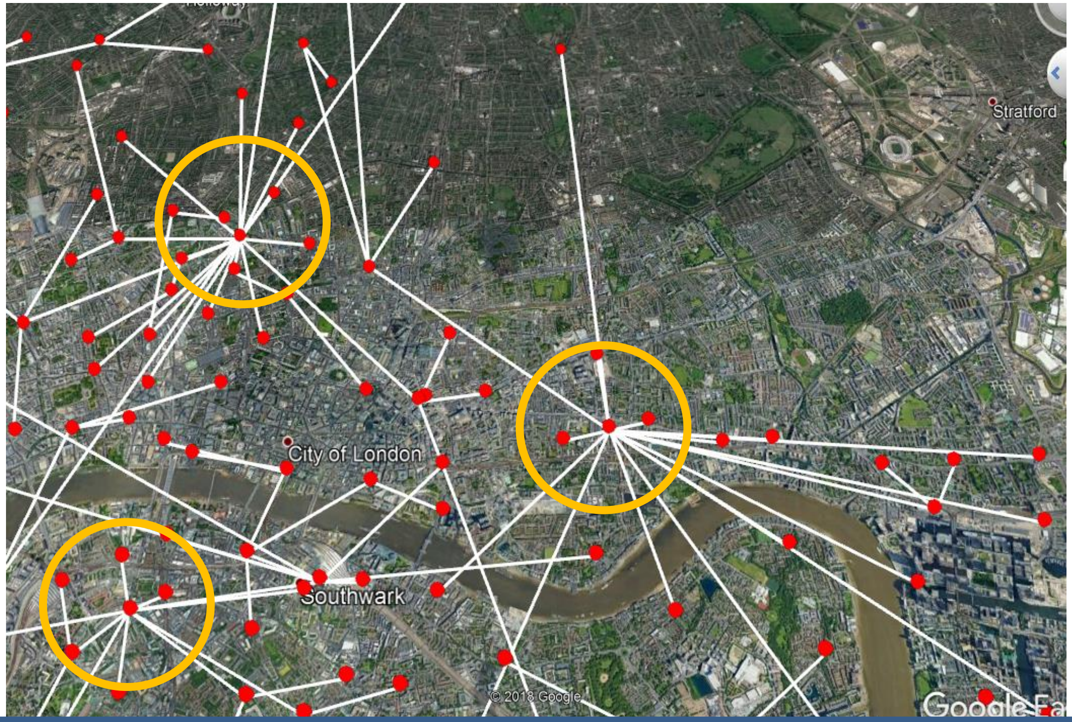
Source: GSMA Spectrum for Wireless Backhaul (Feb 2021)

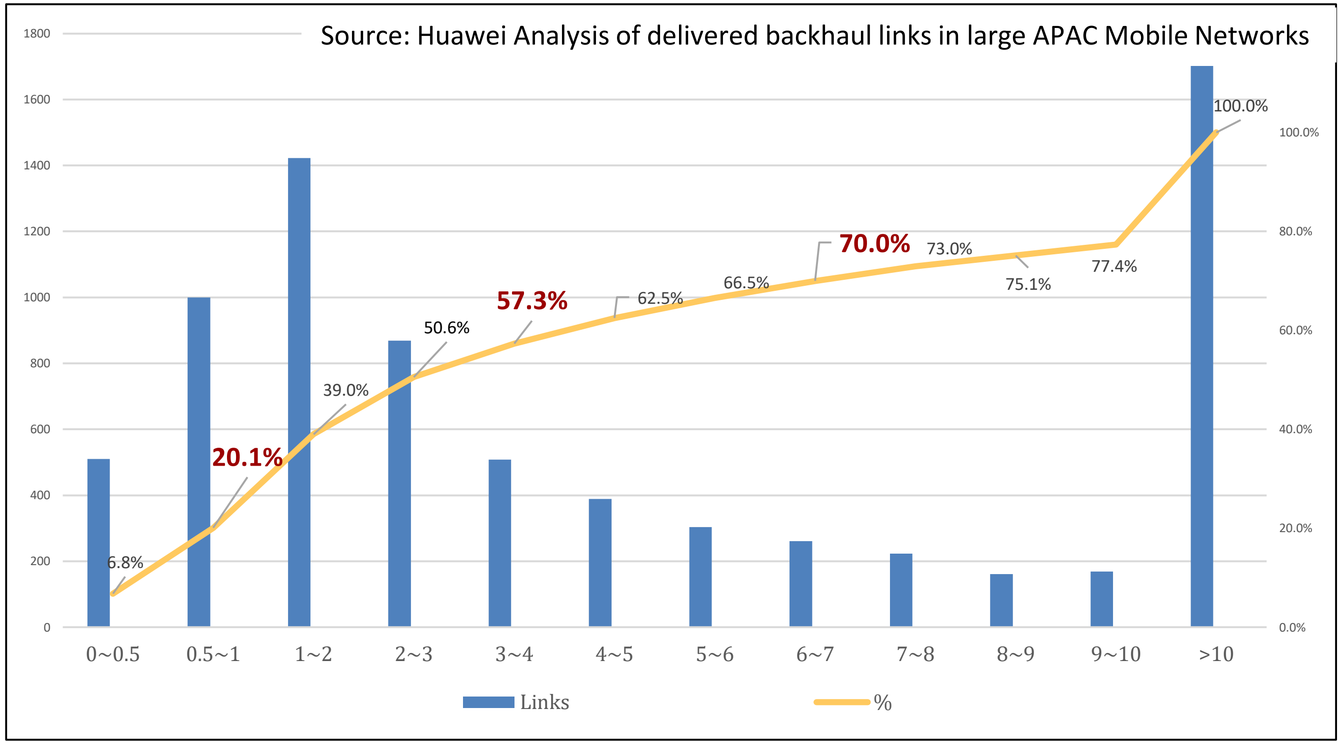
- **Over 70%** of macro sites connected with microwave and millimeter-wave backhaul, with significant regional differences
- **E-Band** applications growing fast at more than 50% CAGR
  - >150k links in operation
  - >25% of total MW + mmWave shipments in 2020
- Necessity of spectrum regulations and licensing at E-Band to incentivize a Fast Time To Market deployment of high throughput 5G services

More than 4 Million links in operation worldwide

Wireless backhaul trends

- **Long term “x-haul” capacity increase to**
  - 5 Gbit/s to rural and suburban sites
  - 10 Gbit/s to suburban and urban sites
  - 25 Gbit/s for future hot spots in dense urban sites
- **Star-topologies (hub and spikes)**
  - shorter network (one hop from fiber PoP to the tail site)



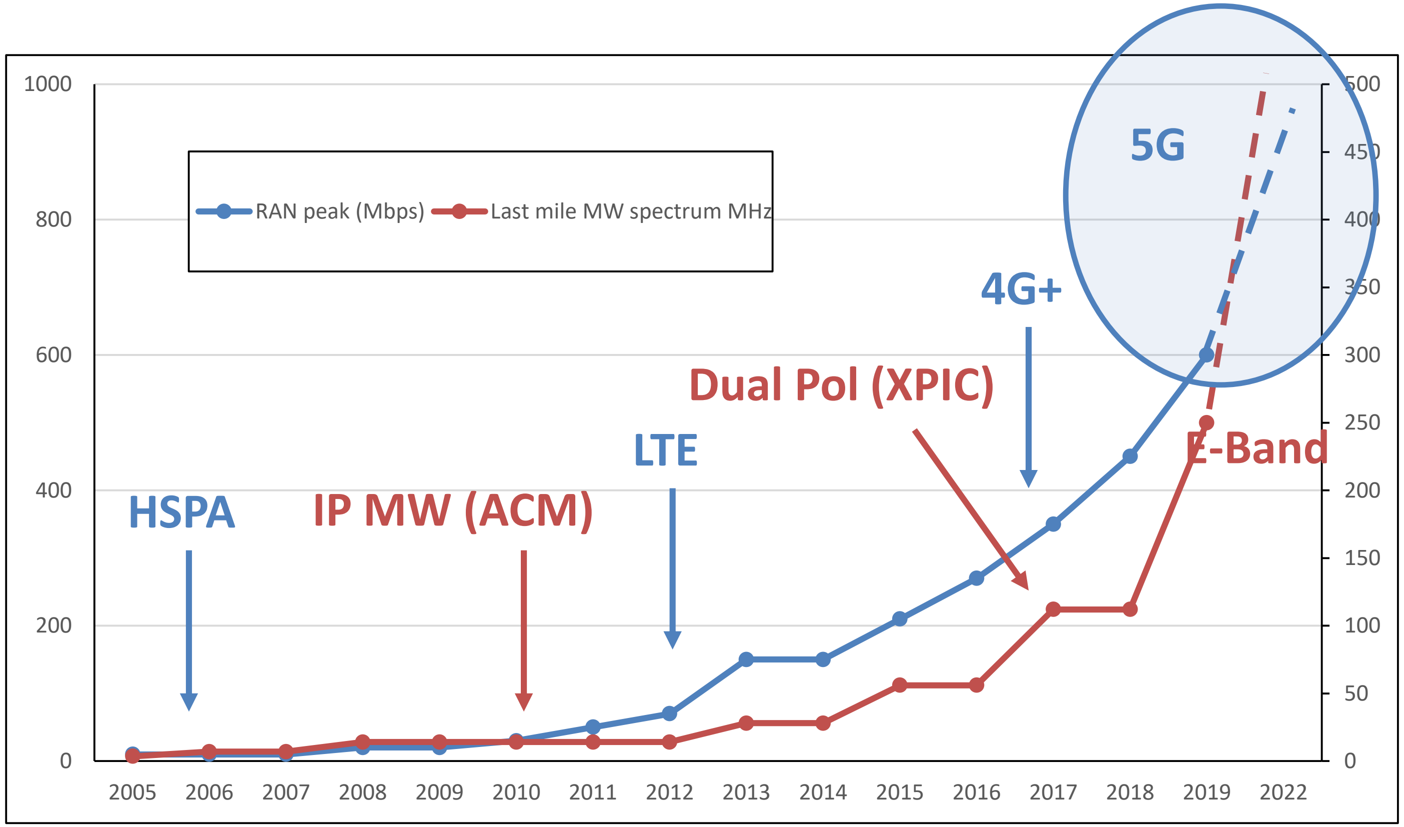


- **Shorter hops to tail site**
  - 20% of the link shorter than 1km → **E-Band** (future W/D-Band)
  - 60% of the links shorter than 4km → **E-Band + MW (BCA)**
  - 70% of the links shorter than 7km
  - Further densifications in dense urban scenarios (<300m)

Calculated in rain region P

Big opportunity for E-Band and BCA links in urban and dense urban scenarios

Economics of Backhaul are Changing Rapidly

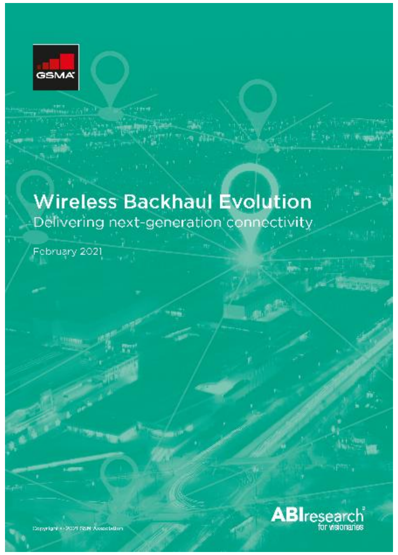


During the past 10 years

- **MW capacity needs for Mobile Operators** increased **x 15** for delivering higher peak speeds
- **MW Spectrum** in the 6 – 42 GHz is not enough for delivering expected 5G capacity; that's why offload to E-Band spectrum is taking place

Spectrum fees have grown into one of the major single items in an Operator's TCO

- Raw cost of spectrum per MHz is sometimes based on formulas born when 3.5 – 7 – 14 MHz were the channel sizes of choice



GSMA launched a report to tackle the issue of backhaul spectrum crunch and costs

ISG mWT 2023-24 work plan (1)

- Modernization of MW and mmWave backhaul to better fit 5G deployments
  - Introduction of new technologies
    - Innovative antennas
    - Interference mitigation and cancellation techniques
  - New way of evaluating backhaul performance, new KPIs based on:
    - Evolution of the transported services
    - From availability of backhaul capacity to actual traffic (BTA – Backhaul Traffic Availability) weighing the microwave or millimeter-wave link outage with the RAN traffic cumulative distribution function
    - BTA values targeting End-to-End end user satisfaction (Backhaul + radio to UE)
  - Impact on spectrum regulations and standards, moving from individual links to “hub” systems of PtP links sharing and managing area radio resources
- Spectrum Agenda, contribute to improve spectrum regulations and licensing in order to better fit 5G requirements and technology evolution
- Go beyond 90 GHz
  - “Consolidate” W-Band and D-Band (applications, equipment standards, spectrum regulations, …)
  - Explore applications and ensure availability of spectrum for frequencies above 175 GHz

ISG mWT 2023-24 work plan (2)

- Analysis of wireless front-haul
  - Systematic discussion in ISG mWT collecting information and different views from both operators and vendors on requirements, applications, etc.
  - Potential drive of the specifications in order to make it more “wireless transport friendly”
  - Analysis of potential impacts on E-Band and upcoming W-Band and D-Band.
- Networking and automation aspects
  - SDN related activities
    - Continue the in-progress activities
    - Automation of E2E Ethernet/IP packet switching and routing services
    - New use cases
  - MW and mmWave backhaul/x-haul support of E2E network slicing
  - Security aspects

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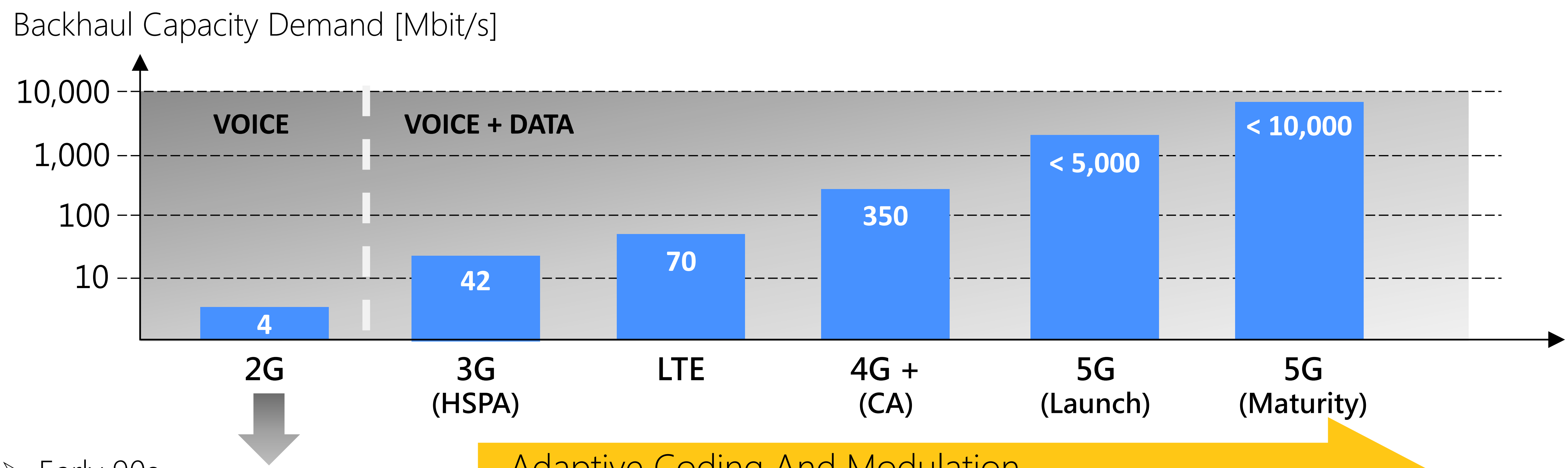
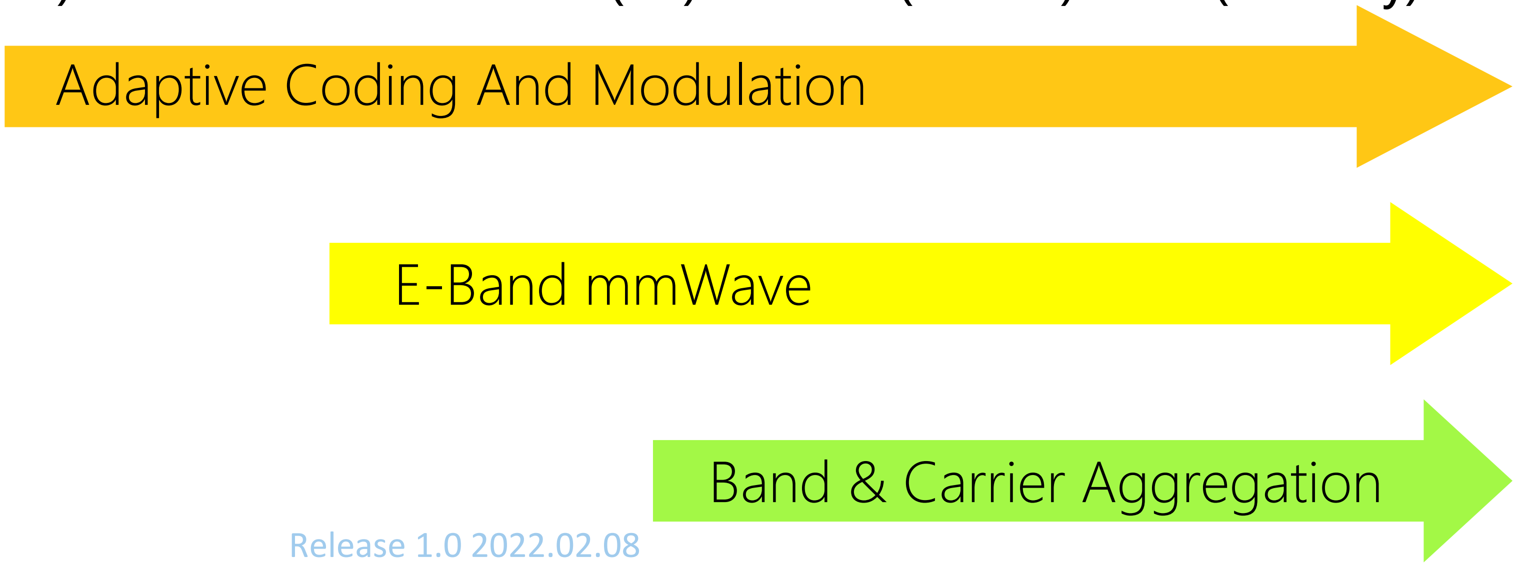
Wireless Backhaul Evolution



- Early 90s
- E1 (2 Mbps) TDM interface transported over PDH MW links
- 1 single static modulation
- BH planning based on link outage = voice service outage



ETSI ISG mWT Activity On "New KPIs For Planning"

Background

MW/mmWave wireless Backhaul **extra cost** due to link **over-engineering** is not affordable any more in terms of spectrum resources (license fees), size of antennas, products and energy consumption

Matter of Fact

Today link planning approach based on Committed Information Rate (CIR) and Peak Information Rate (PIR) does **not consider** that **99%** of the Backhaul traffic is **data**

Goal

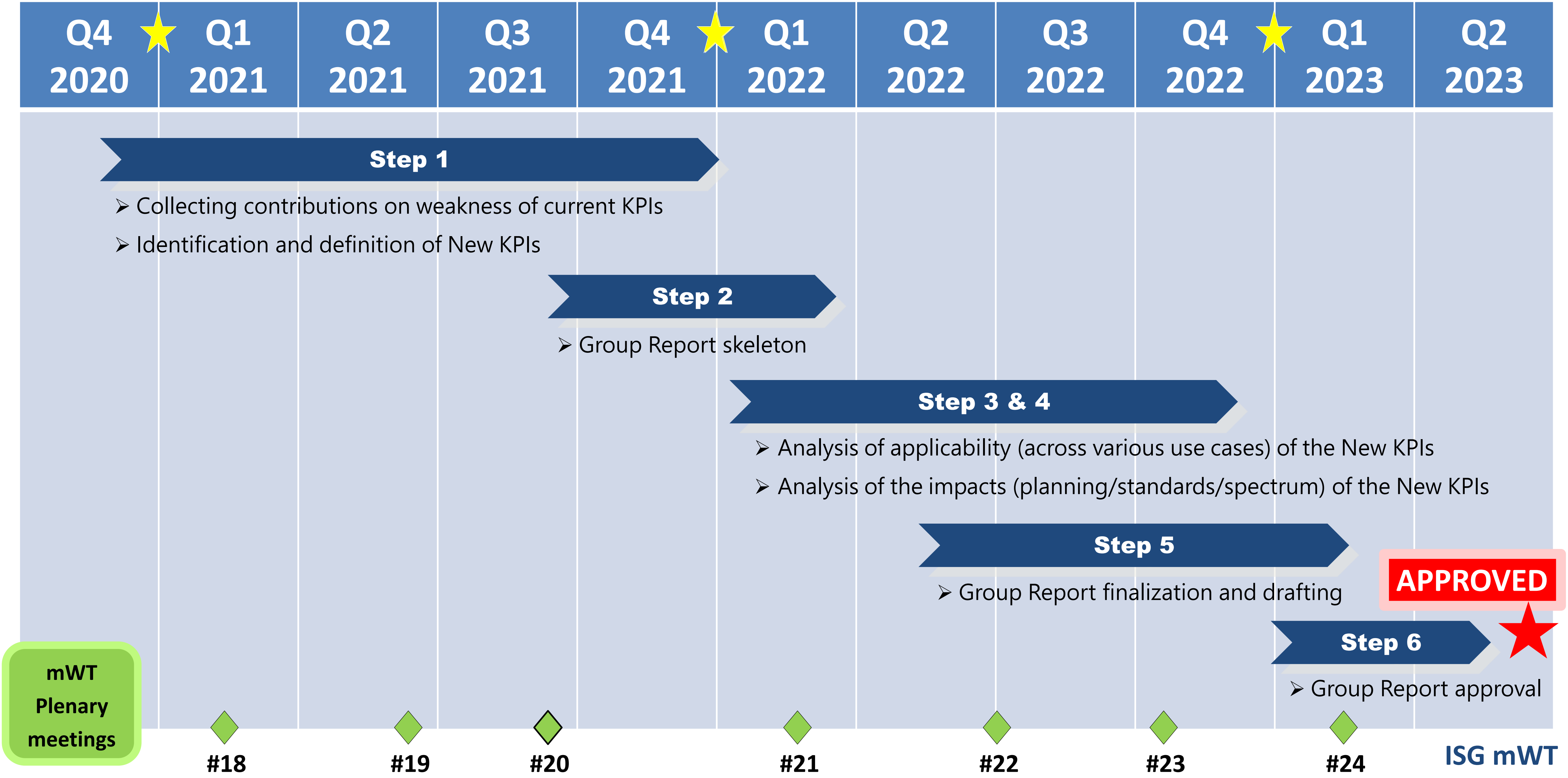
Definition of **new KPIs for planning** MW/mmWave **Backhaul links**, accounting for:

- more challenging requirements coming from 5G deployment
- new technologies aiming at more efficient interference mitigation and cancellation
- increase of use of spectrum in the mmWave range, both stand-alone and aggregated (BCA)
- different typologies and mix of services transported

Vision

Backhaul link seen as a part of the overall **E2E User Experience**, in terms of **minimum rate availabilities** and optimal response to the specific **RAN traffic demand**

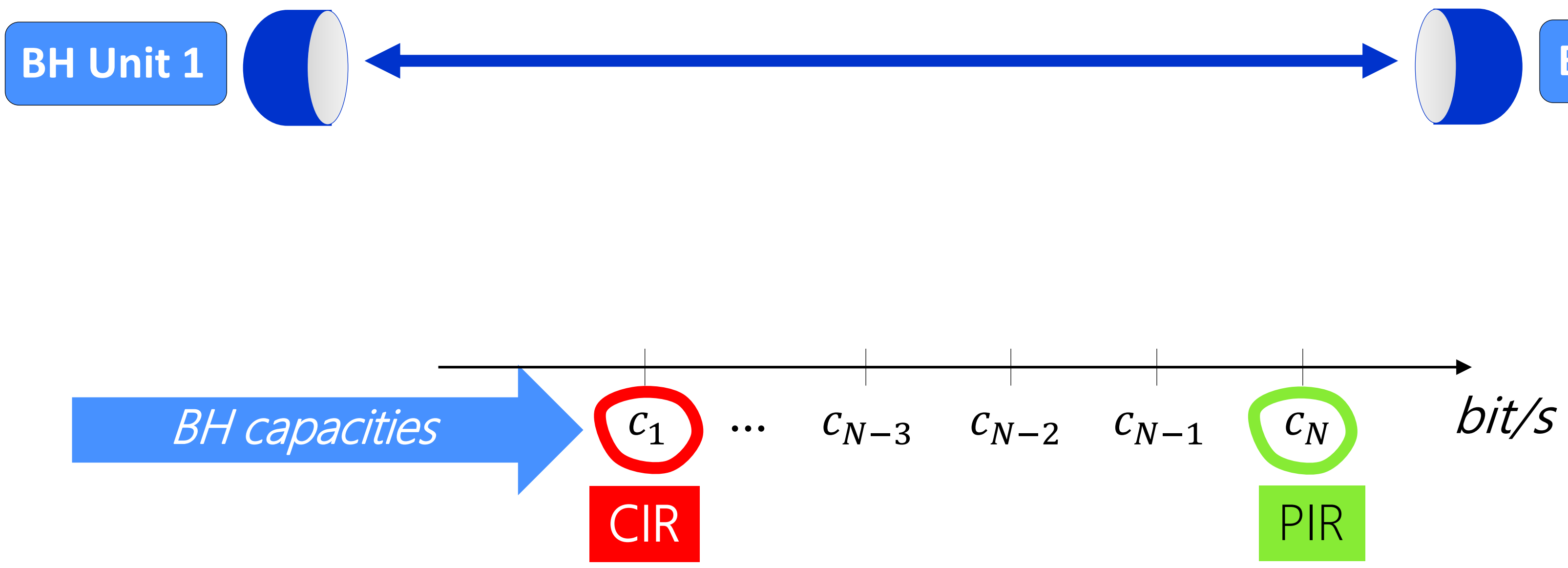
Work Item 28 Roadmap: **2+** years and **30+** contributions



ISG mWT

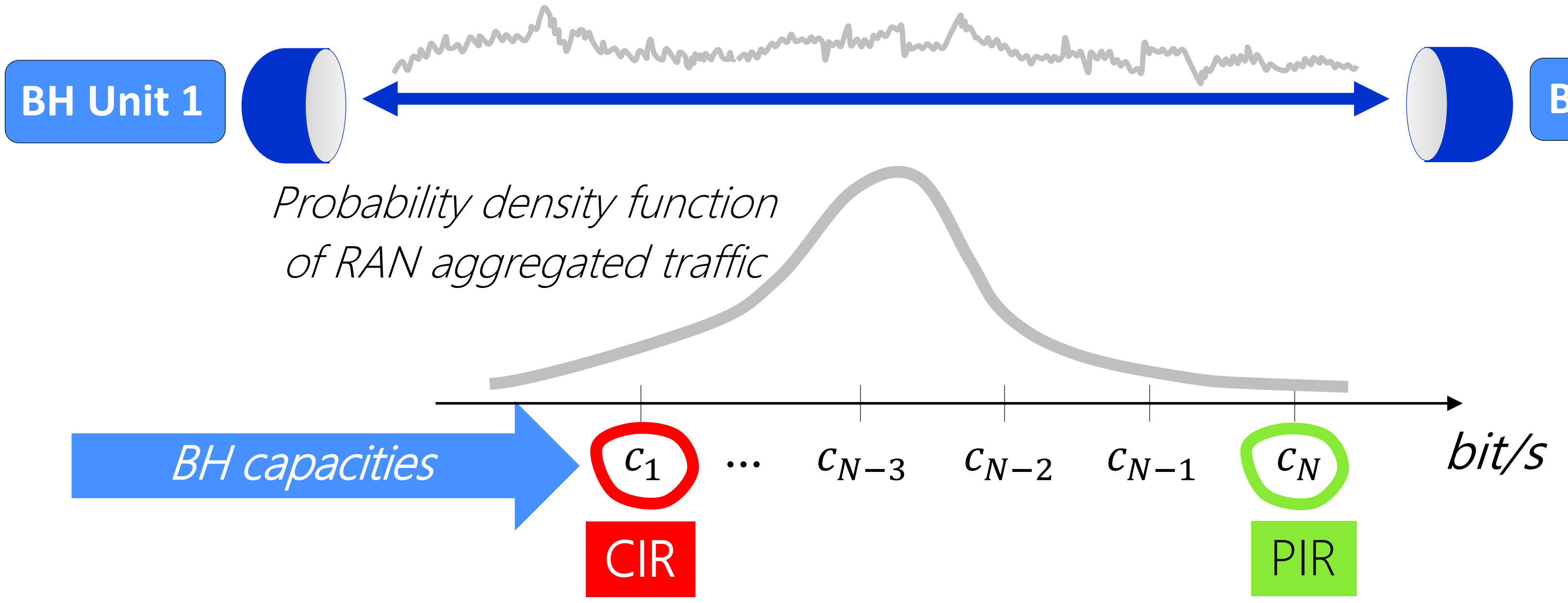
Content

Current Planning Of Backhaul Links



- **Minimum link capacity** (CIR) to be guaranteed with a target link availability (**4** to **5** nines)
- **Maximum link capacity** (PIR) based on RAT and to be guaranteed with a less conservative availability target (**3** nines, **2** nines), with no strong rationales

Current Planning Of Backhaul Links



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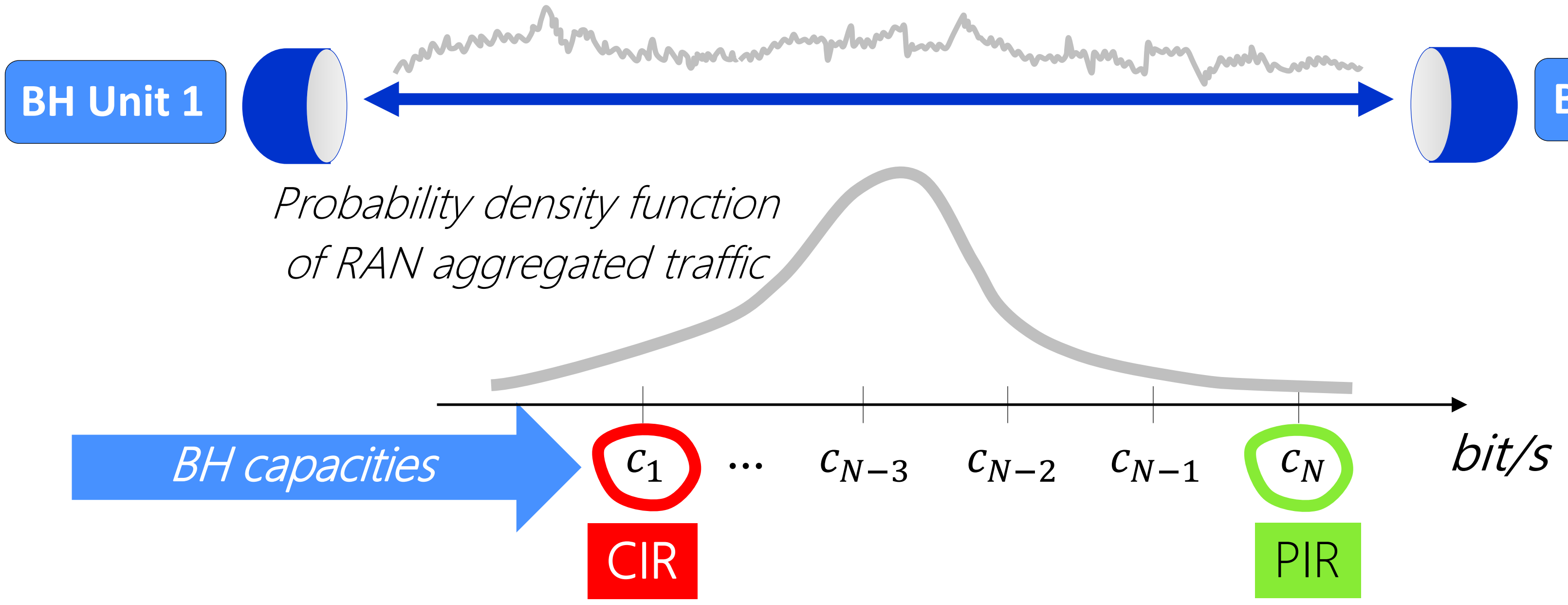
Traffic demand is a continuous set of values with certain occurrence probabilities, and this is **not** currently **taken into account**

Current Planning Of Backhaul Links



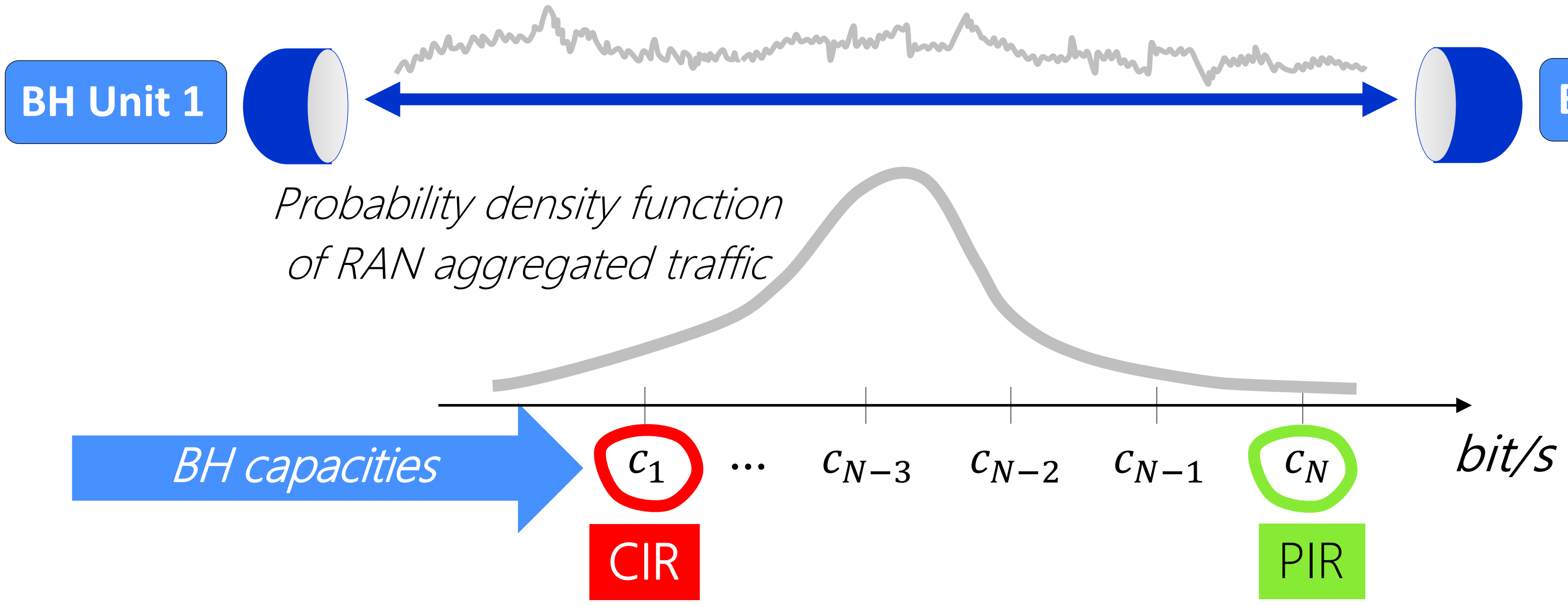
ARE WE OVER-ENGINEERING THE LINK? …or *equivalently…* **IS TCO TOO EXPENSIVE?**

currently included

Perceived PIR outage probability = PIR outage probability

*(**due to rain** or other adverse propagation condition)*

Current Planning Of Backhaul Links



ARE WE OVER-ENGINEERING THE LINK? …or *equivalently*… **IS TCO TOO EXPENSIVE?**

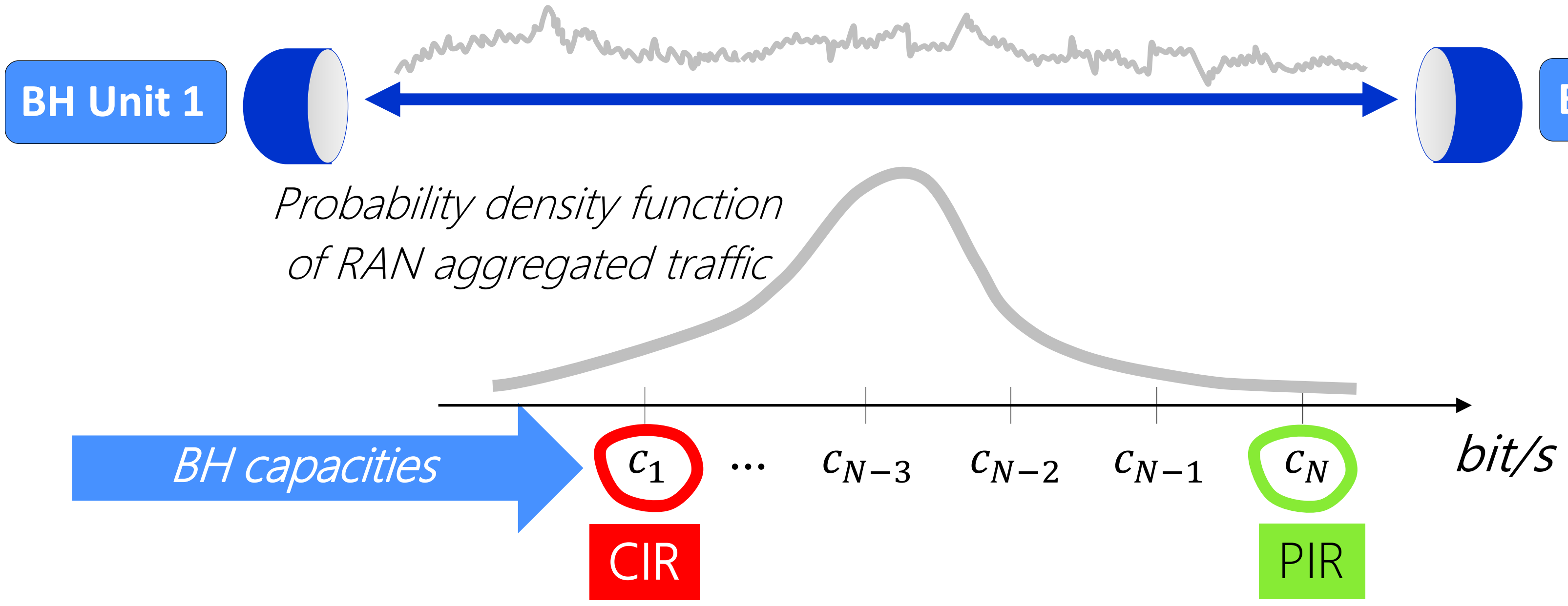
currently included | **currently not included**

Perceived PIR outage probability = PIR outage probability X Probability PIR is required

*(**due to rain** or other adverse propagation condition)*

(depends on the RAN traffic statistics)

Current Planning Of Backhaul Links

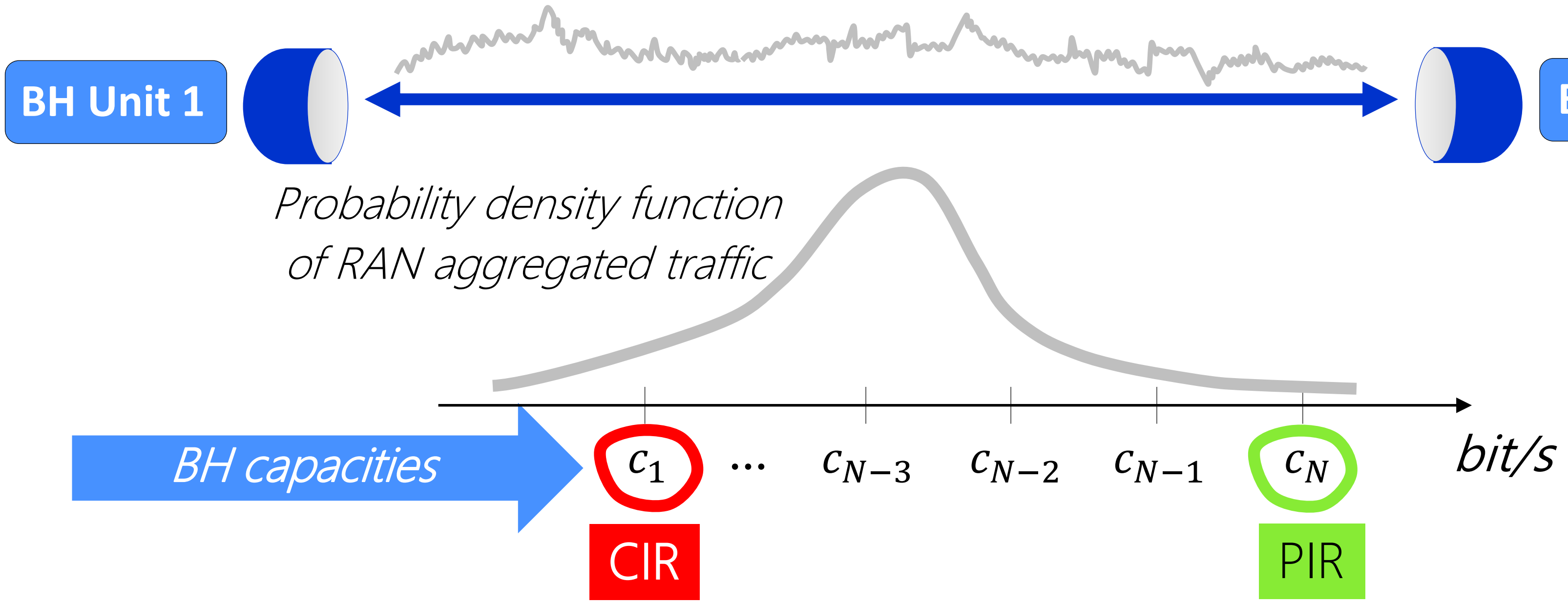


ARE WE OVER-ENGINEERING THE LINK? …or *equivalently…* **IS TCO TOO EXPENSIVE?**

		currently included		currently not included
Perceived PIR outage probability	=	PIR outage probability *(**due to rain** or other adverse propagation condition)*	X	Probability PIR is required *(depends on the RAN traffic statistics)*

Why requiring **99.9% availability** for a **peak rate** that is demanded by the RAN with a **small probability** ?

Current Planning Of Backhaul Links



ARE WE OVER-ENGINEERING THE LINK? …or *equivalently*… **IS TCO TOO EXPENSIVE?**

New KPIs for Backhaul Planning tailored to the **expected traffic statistics** of the links are **needed !**

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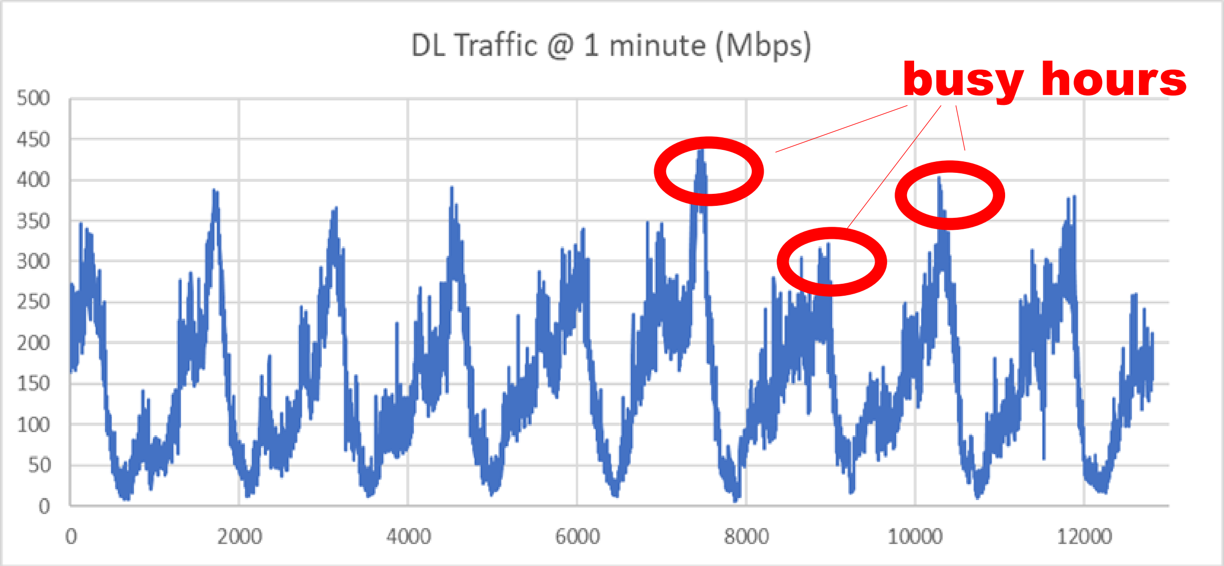
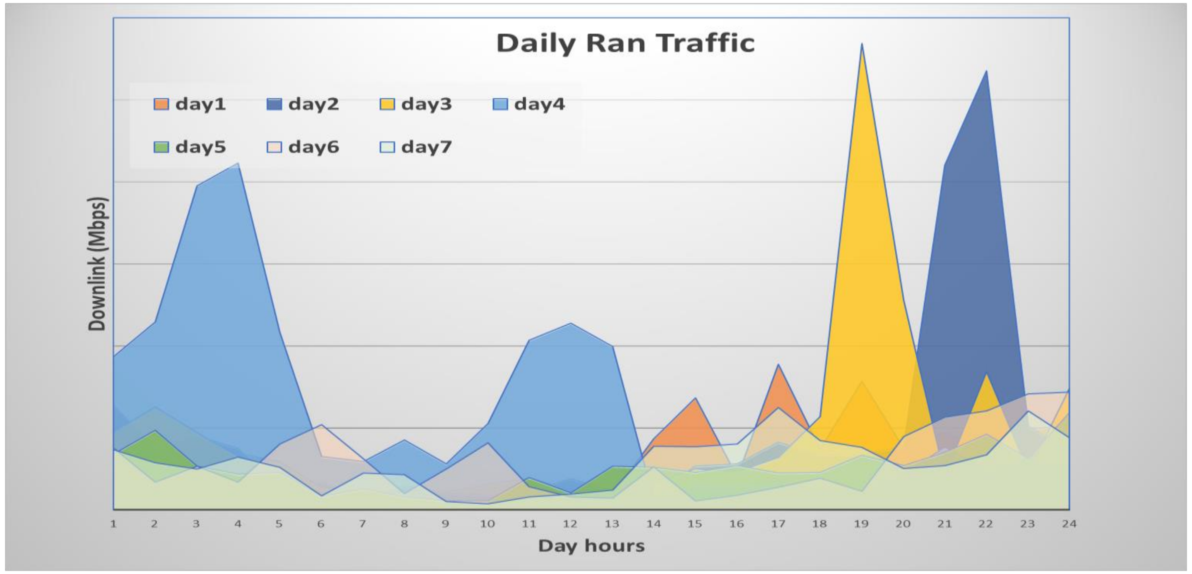
1st Actor: RAN Traffic

- **RAN traffic** is a **statistical random variable** determined by:
  - end users number, type, habits and behavior
  - end users device performance and geo-distribution
  - deployed RATs
  - RAN design in terms of coverage and interference
  - etc.

RAN traffic pattern example during 10 days



RAN site daily traffic patterns for 7 days



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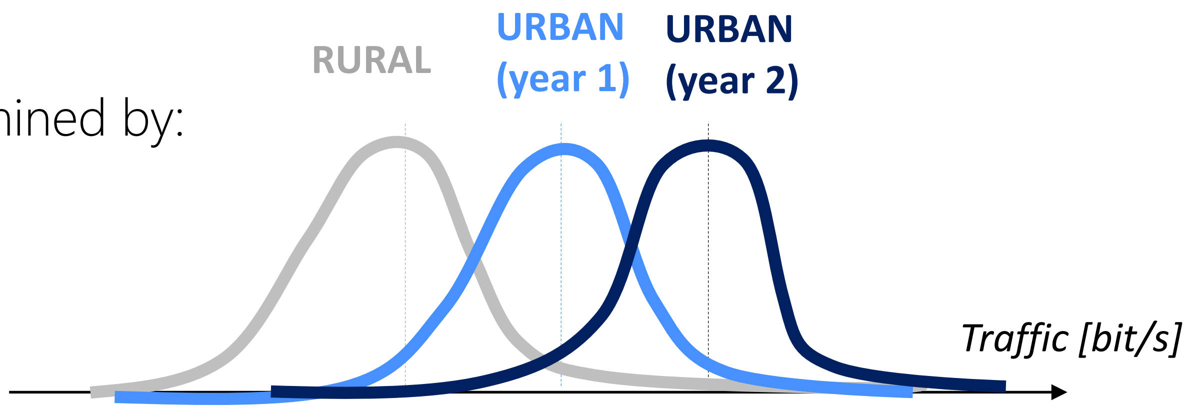
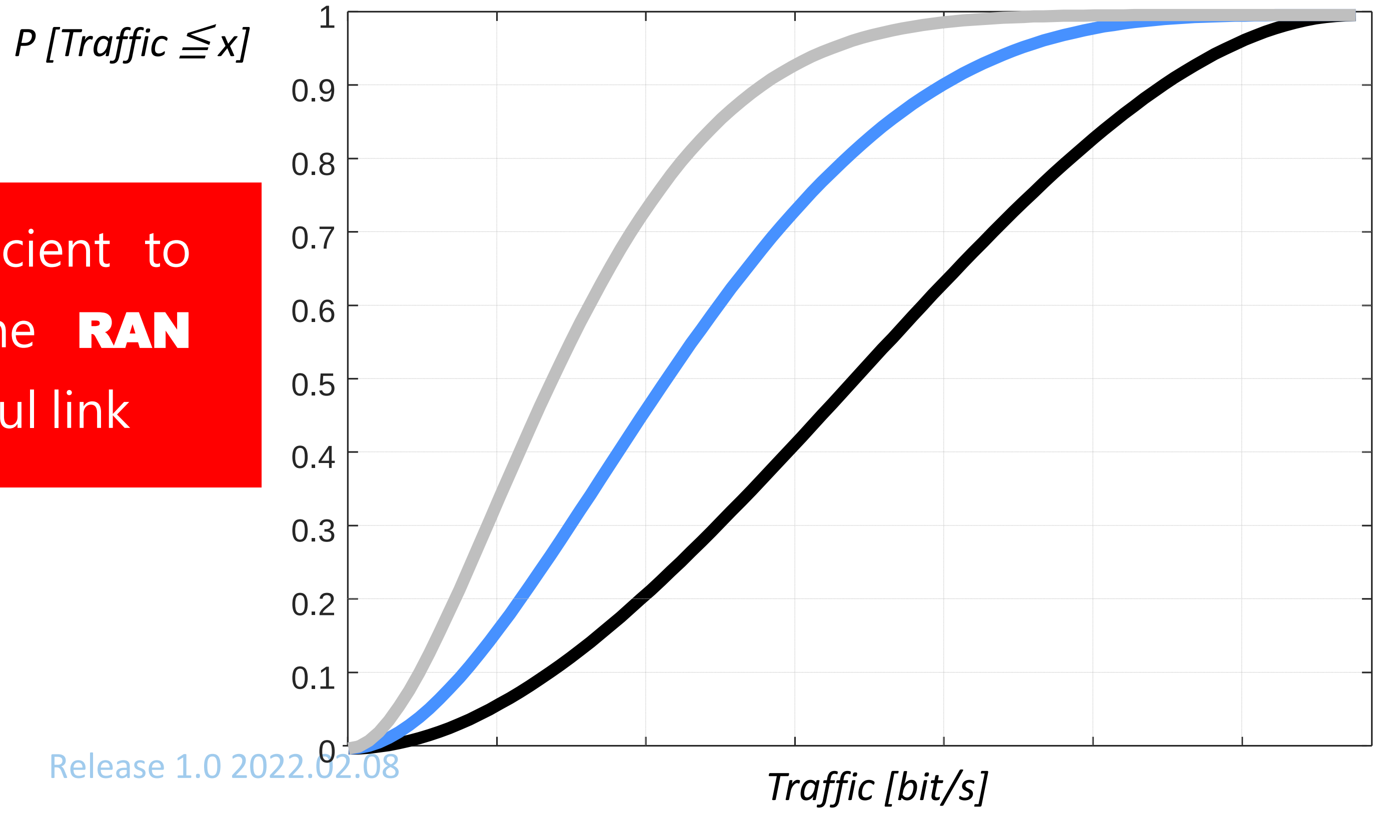
  - RAN design in terms of coverage and interference
  - etc.

The **only PDF (or CDF) curve** is sufficient to provide the **overall description** of the **RAN traffic** that shall be delivered by the backhaul link

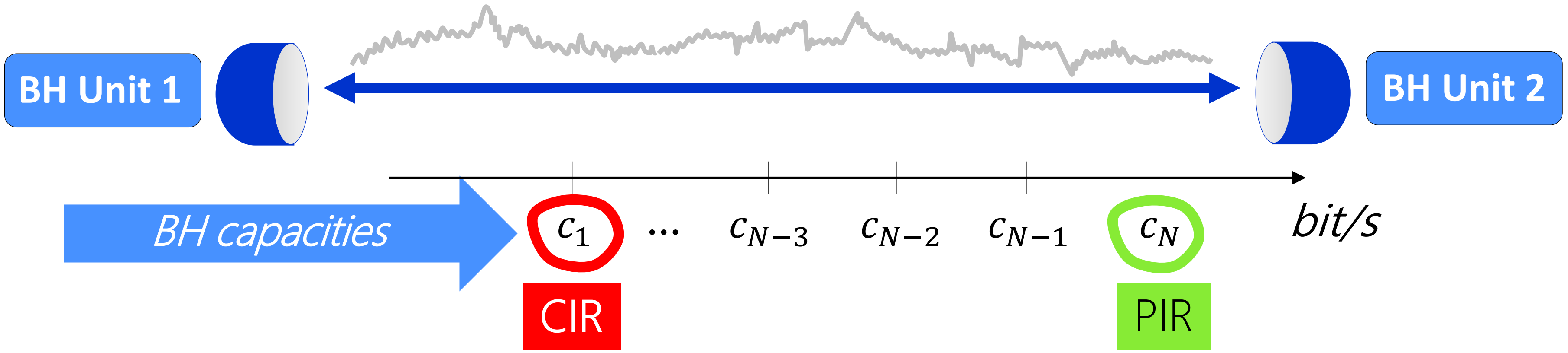
Probability density function of RAN aggregated traffic



Cumulative distribution function of RAN aggregated traffic

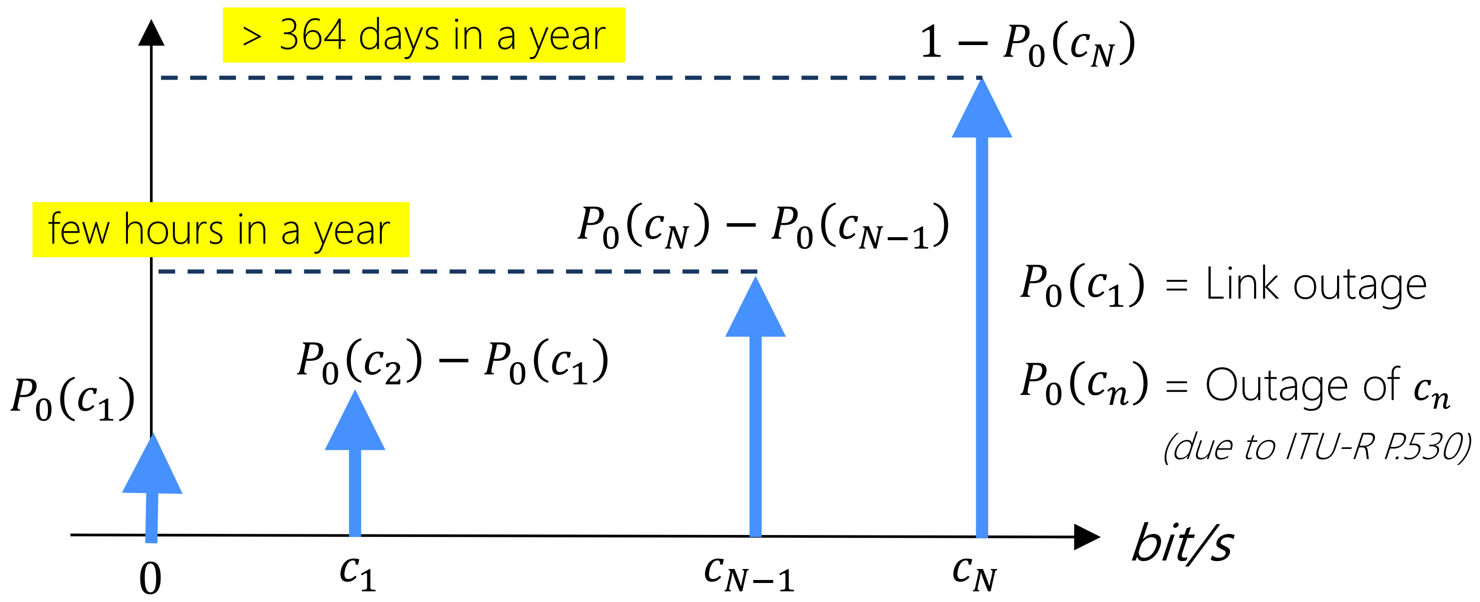


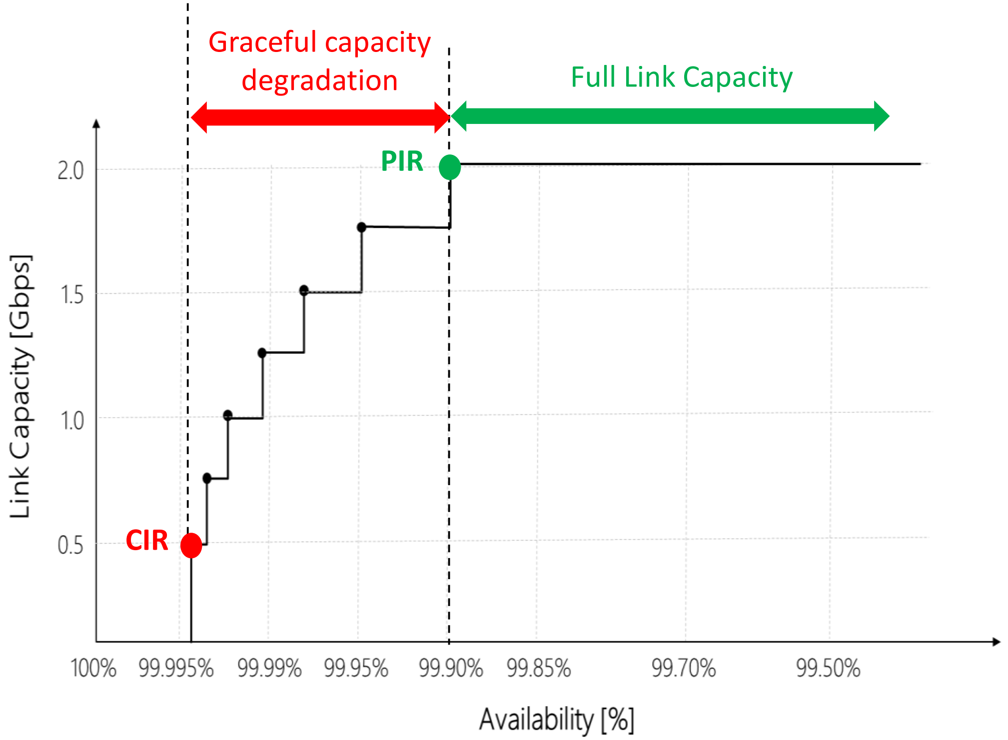
2nd Actor: Backhaul Capacity



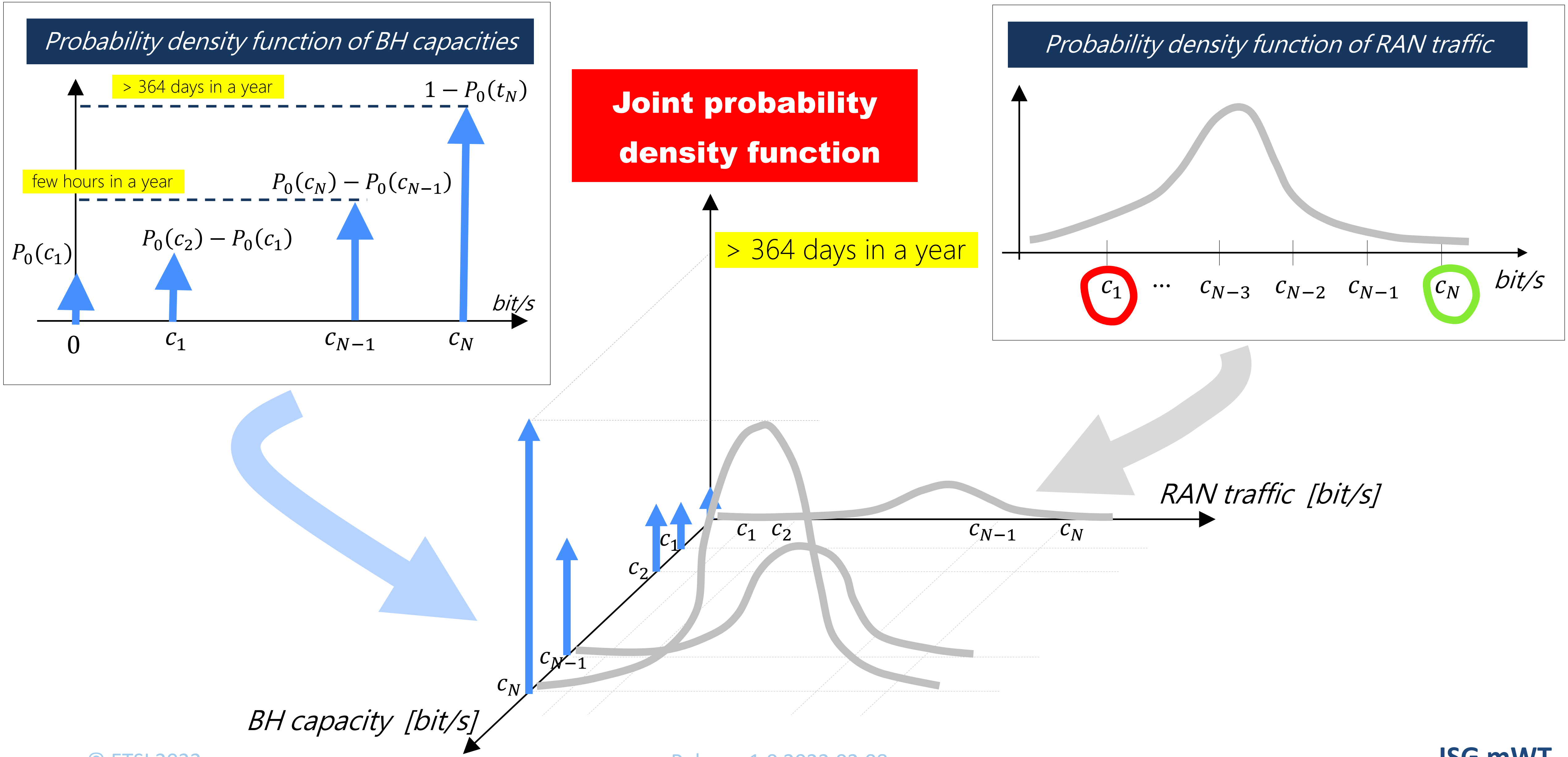
The **Backhaul capacity** provided by a link using ACM is a **statistical random variable**

Probability density function of BH capacities





Putting BH Capacity And RAN Traffic Together



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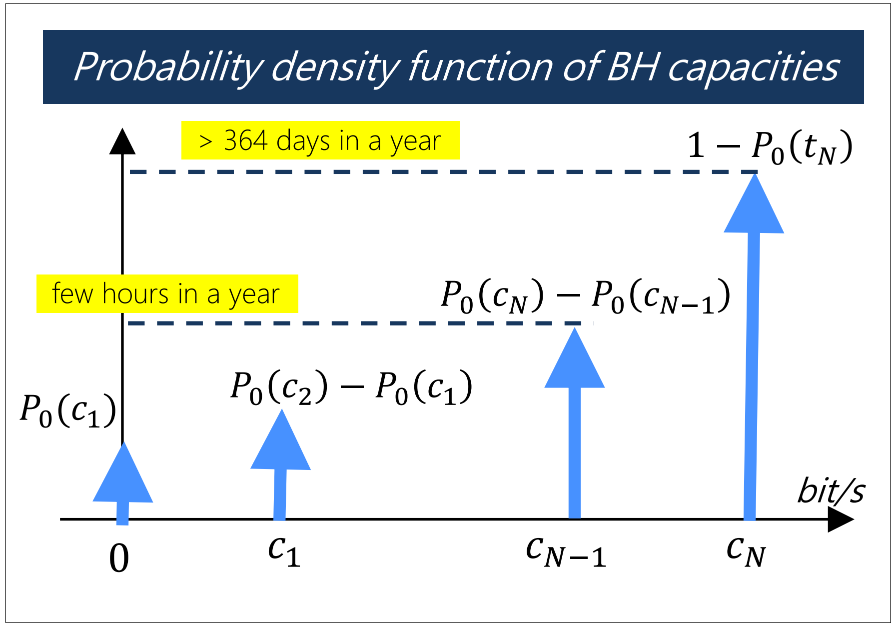
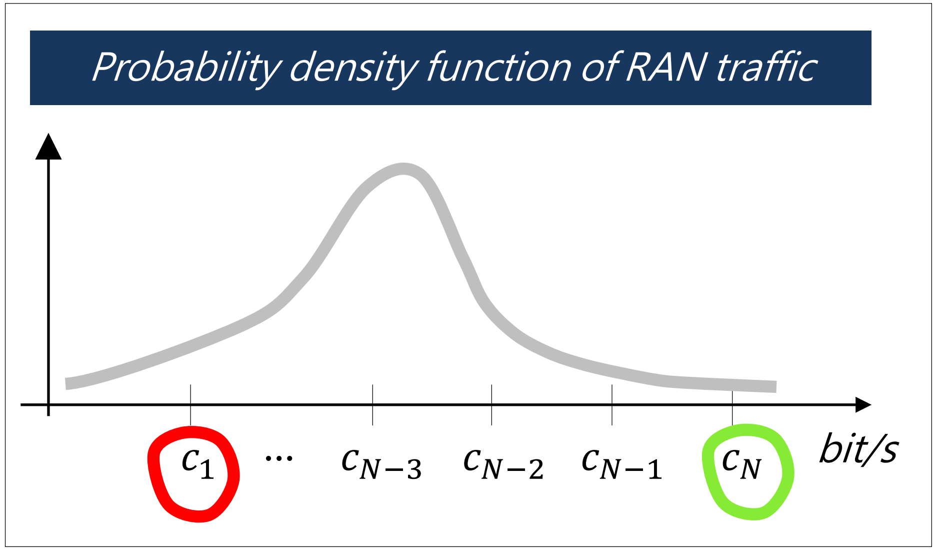
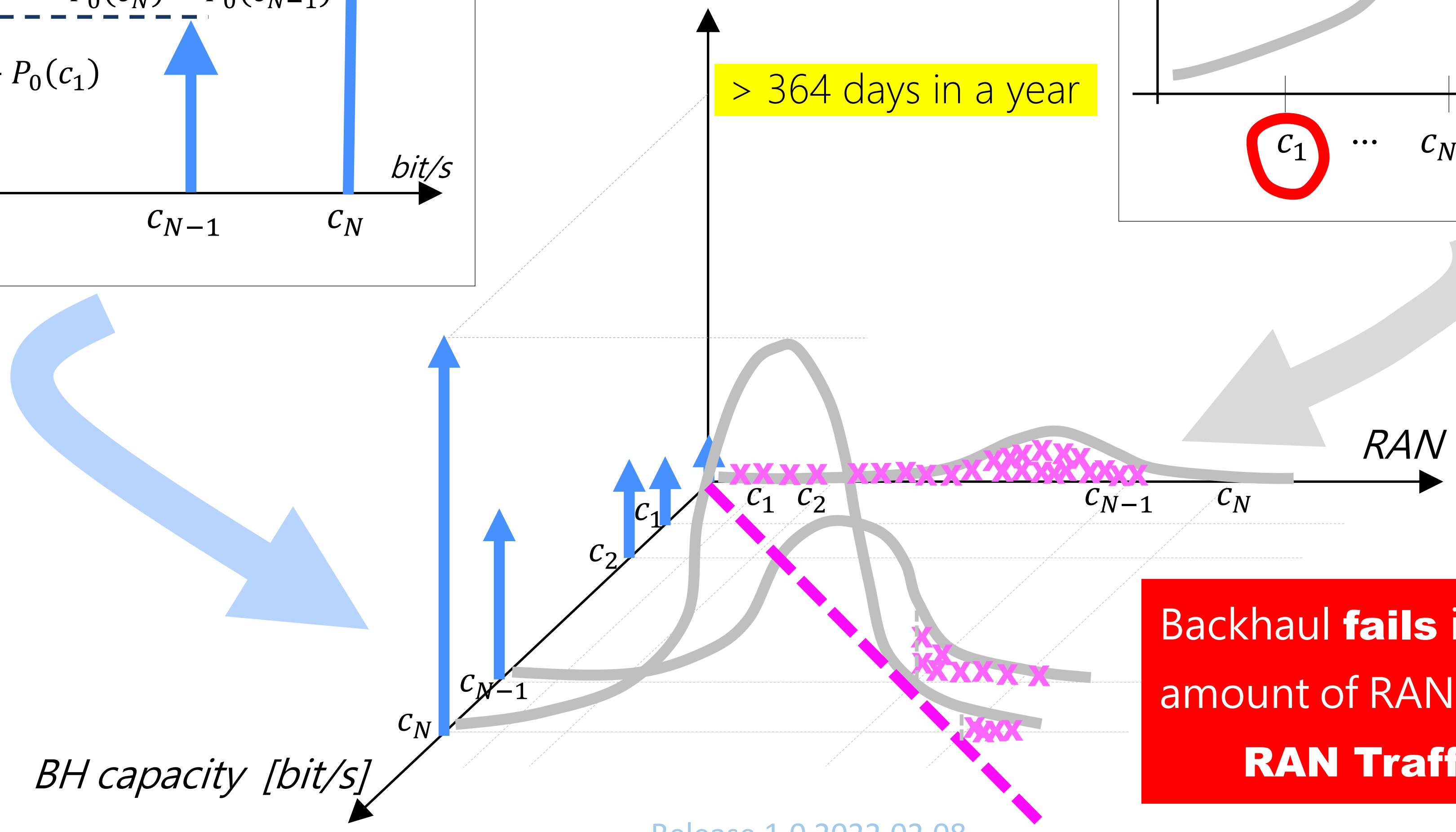




Joint probability density function



Backhaul **fails** in delivering the **entire** amount of RAN traffic demand when **RAN Traffic > BH Capacity**

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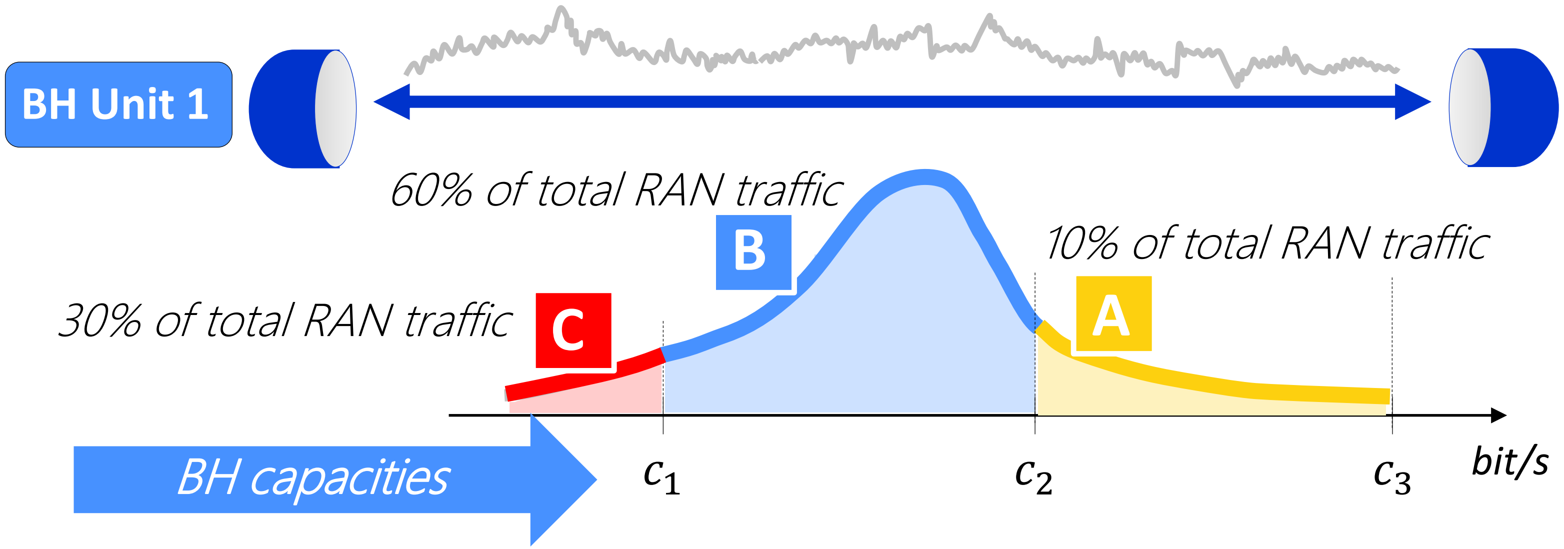
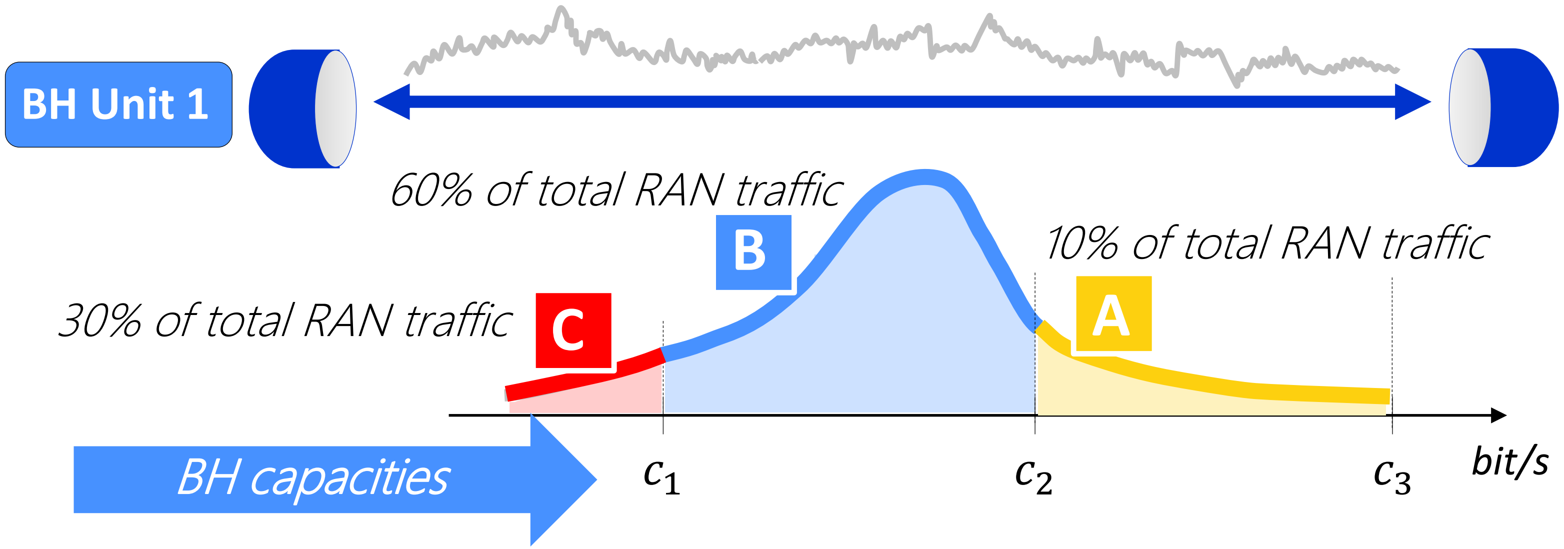
Backhaul Traffic Availability – BTA



Capacity	Outage (P.530)
c_3	0.1%
c_2	0.05%
c_1	0.03%

When does the Backhaul **fail** in delivering the **entire** amount of **RAN traffic demand**?

Backhaul Traffic Availability – BTA



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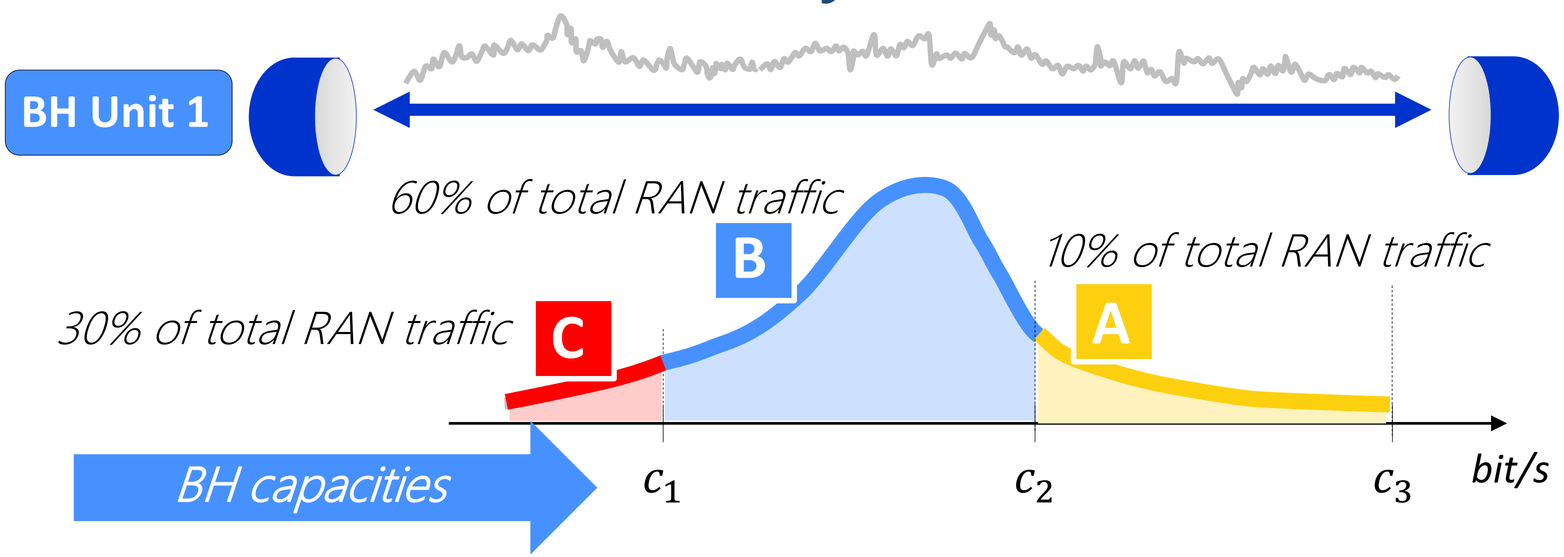
When does the Backhaul **fail** in delivering the **entire** amount of **RAN traffic demand**?

If c_3 is in outage **AND** RAN traffic is in region A 0.1% **X** 10%

Backhaul Traffic Availability – BTA



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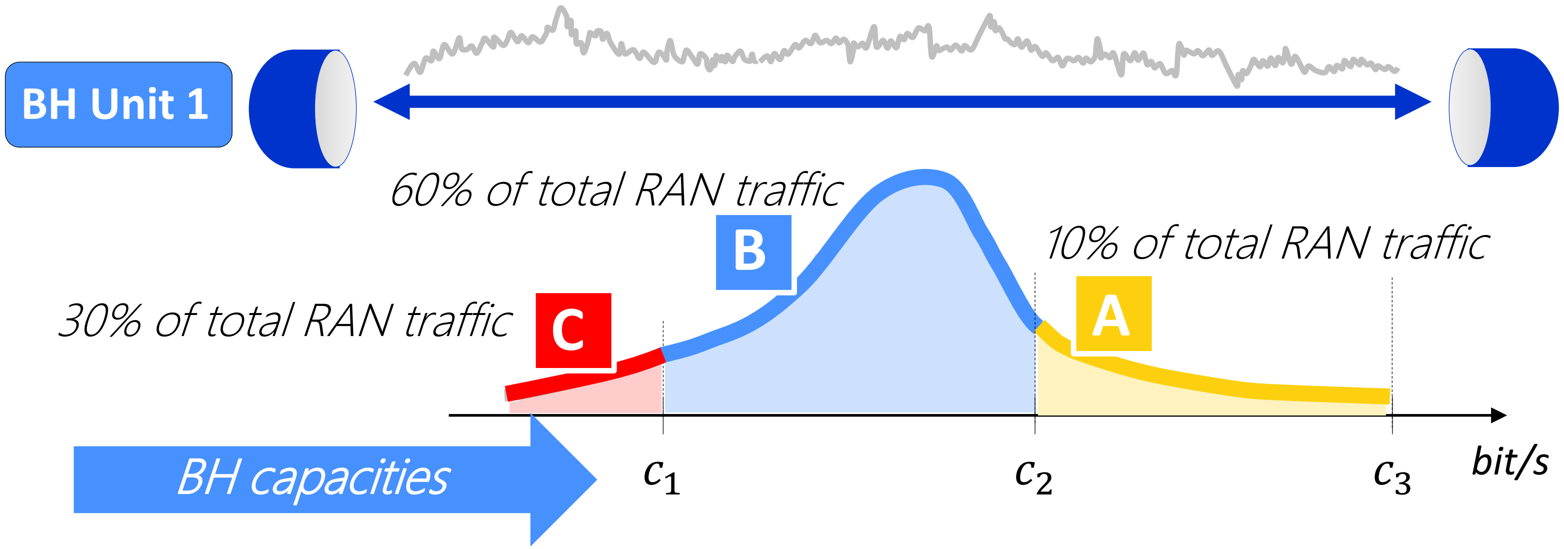
If c_3 is in outage **AND** RAN traffic is in region A 0.1% **X** 10%

OR

If c_2 is in outage **AND** RAN traffic is in region B 0.05% **X** 60%

Backhaul Traffic Availability – BTA



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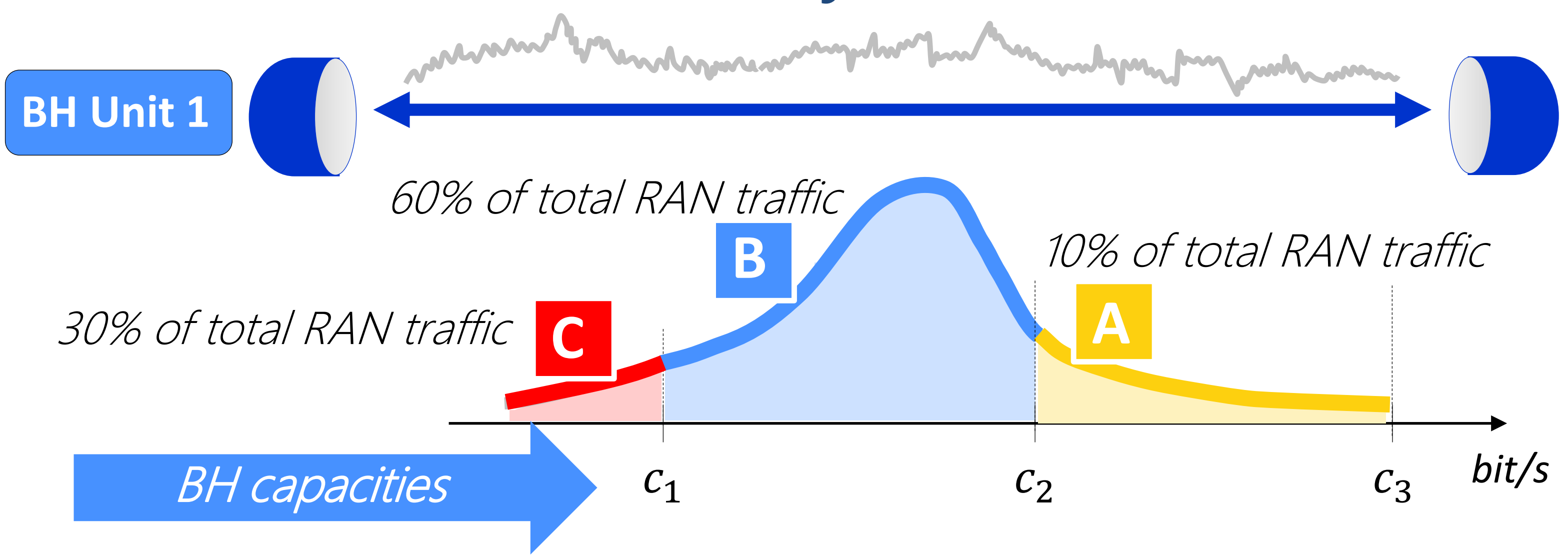
OR

If c_2 is in outage **AND** RAN traffic is in region **B** 0.05% **X** 60%

OR

If c_1 is in outage **AND** RAN traffic is in region **C** 0.03% **X** 30%

Backhaul Traffic Availability – BTA



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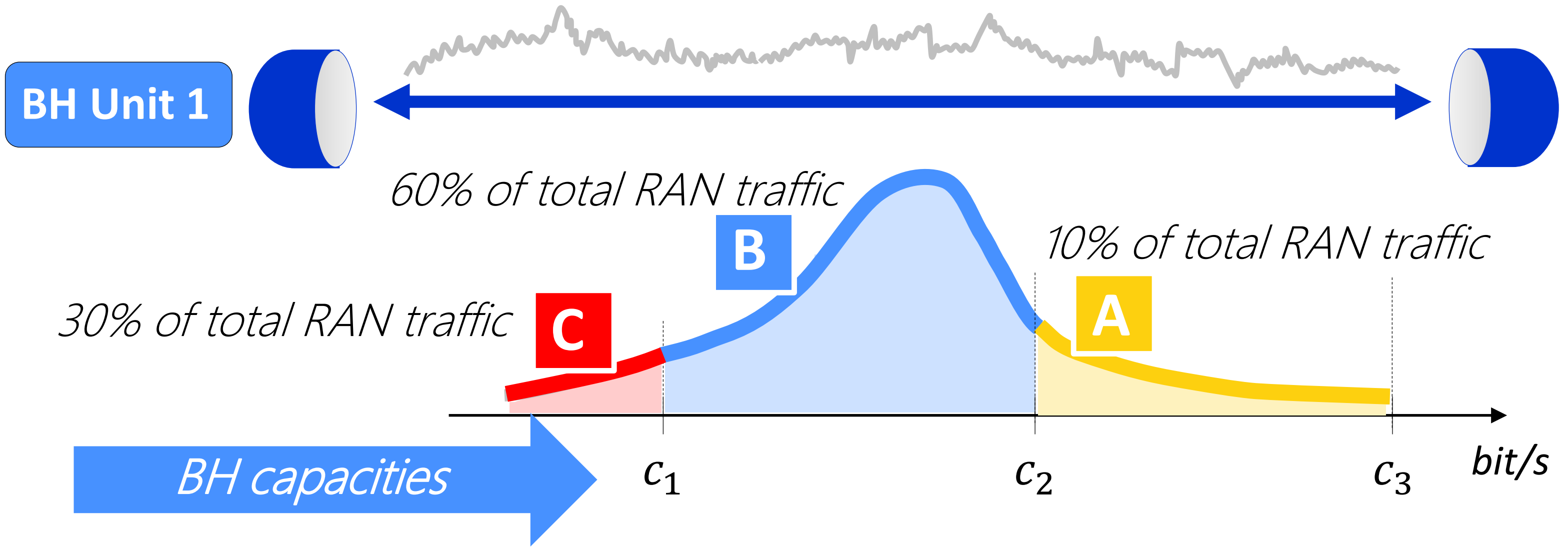
When does the Backhaul **fail** in delivering the **entire** amount of **RAN traffic demand**?

If c_3 is in outage	**AND**	RAN traffic is in region **A**	0.1%	**X**	10%	
	OR				**+**	
If c_2 is in outage	**AND**	RAN traffic is in region **B**	0.05%	**X**	60%	
	OR				**+**	
If c_1 is in outage	**AND**	RAN traffic is in region **C**	0.03%	**X**	30% **=**	**0.049 %**

Backhaul Traffic Availability – BTA



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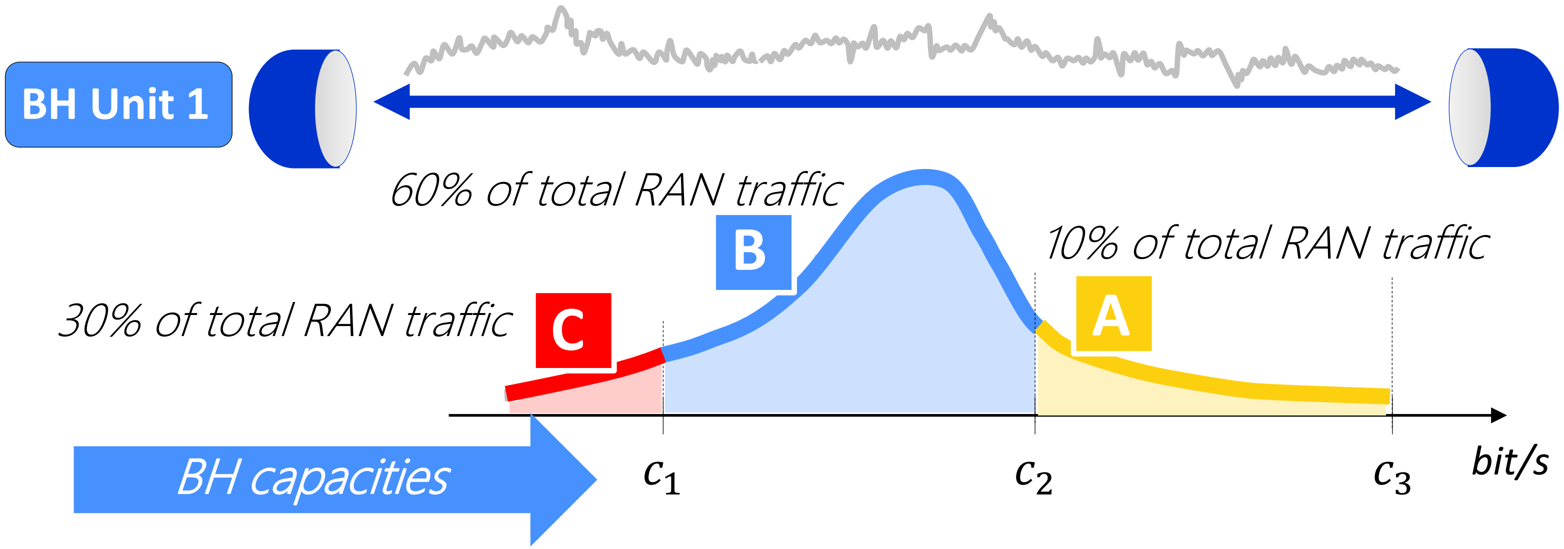
OR **+**

If c_1 is in outage **AND** RAN traffic is in region **C** 0.03% **X** 30% **=** **0.049 %**

Backhaul Traffic Availability (BTA) = 1 – 0.049 % = 99.951 %

Backhaul Traffic Availability – BTA



Capacity	Outage (P.530)
c_3	0.1%
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c_1	0.03%

BTA represents

the probability that the **Backhaul link** is capable to **deliver 100%** of the aggregated **RAN** traffic, therefore with **no impacts** on **End User Experience**

and, consequently

the probability that the **Backhaul link** does **not congest** the aggregated RAN traffic

Backhaul Traffic Availability (BTA) = 1 – 0.049 % = 99.951 %

BTA Mathematical Formulation

$$BTA = 1 - P(T_{RAN} > c_N) - \alpha_{out}(c_N)P(c_{N-1} < T_{RAN} \le c_N) +$$

$$- \alpha_{out}(c_{N-1})P(c_{N-2} < T_{RAN} \le c_{N-1}) +$$

$$- \alpha_{out}(c_{N-2})P(c_{N-3} < T_{RAN} \le c_{N-2}) - \ldots$$

$$- \alpha_{out}(c_1)P(T_{RAN} \le c_1)$$

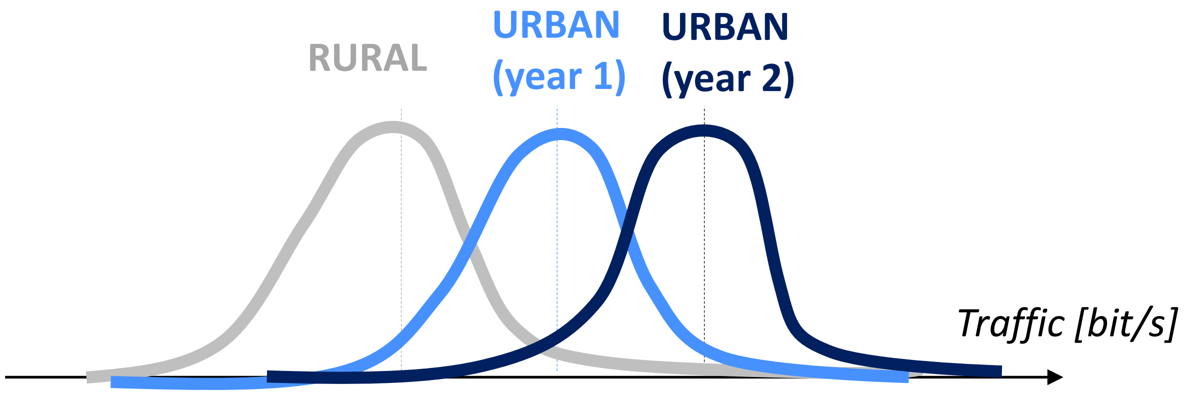
$\alpha_{out}(c_n)$ = outage of Backhaul capacity c_n

(from ITU-R P.530)

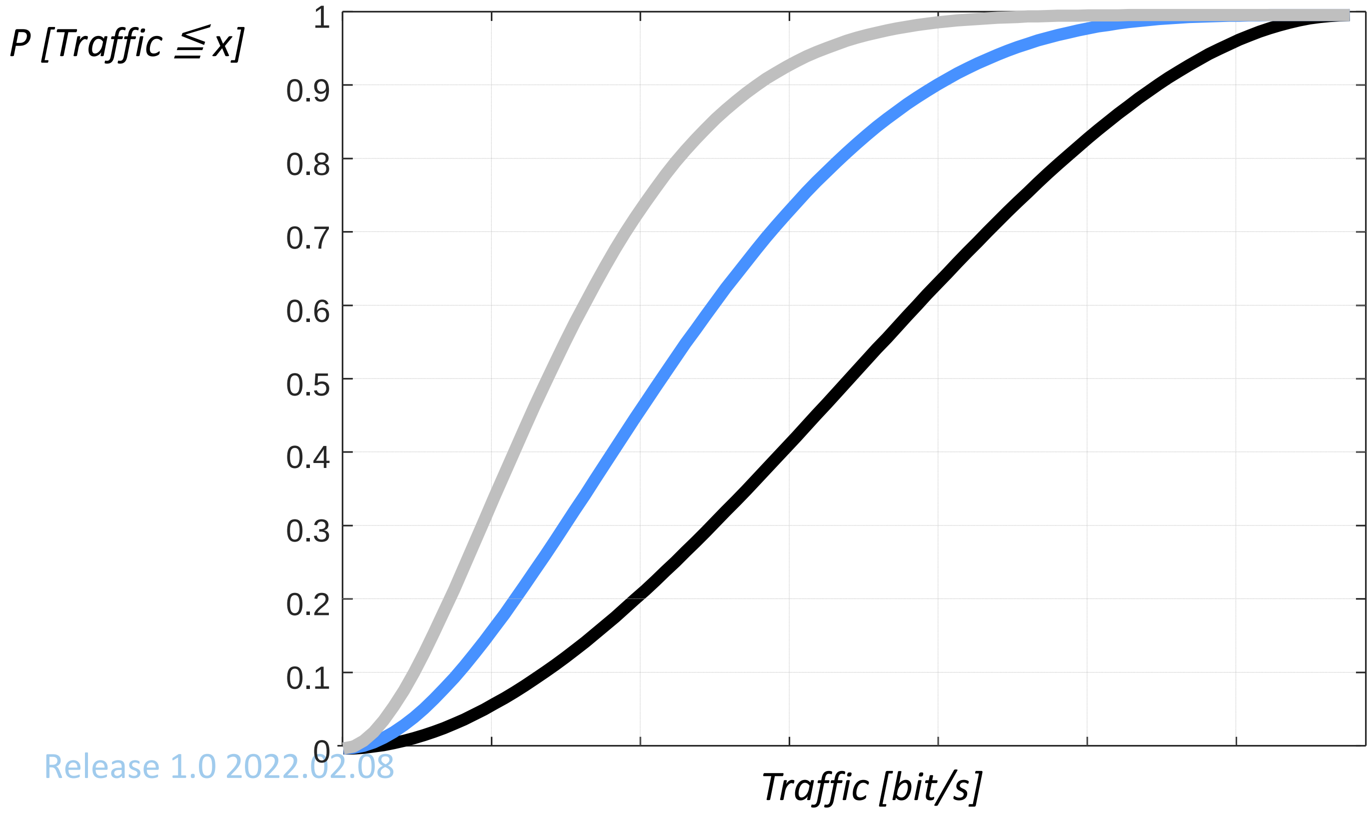
BTA & Traffic Statistics

Planning of Backhaul links with **BTA** metric should be based on specific assumptions on the **traffic statistics** of the hops (that depend on site configurations, traffic load, expected capacity growth, etc.).

Probability density function of RAN aggregated traffic



Cumulative distribution function of RAN aggregated traffic

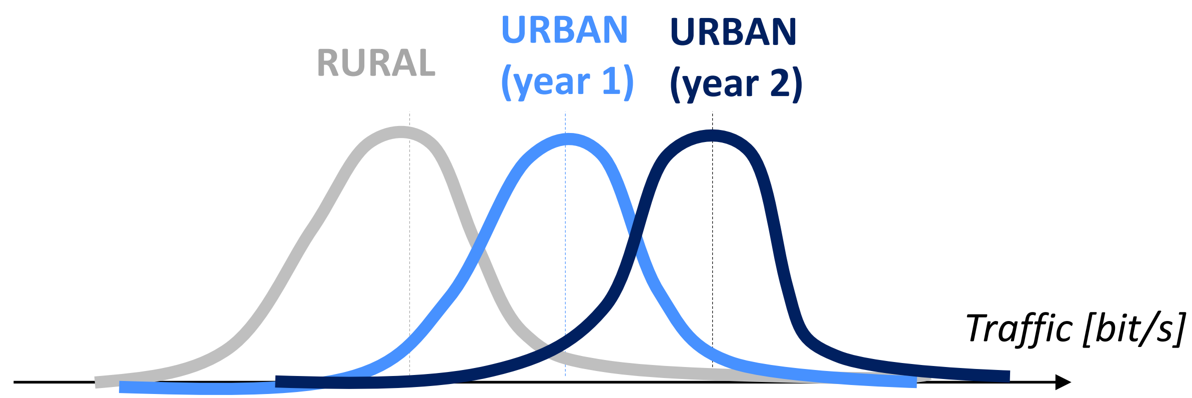


BTA & Traffic Statistics

E-band @ 2 km

E-band 500 MHz Dual Pol, 60 cm antennas *(42 mm/h)*								
762 Mbit/s	1526 Mbit/s	2289 Mbit/s	3053 Mbit/s	3817 Mbit/s	4580 Mbit/s	5344 Mbit/s	6108 Mbit/s	6872 Mbit/s
99,998 %	99,996 %	99,994 %	99,993 %	99,991 %	99,986 %	99,980 %	99,975 %	99,957 %

Probability density function of RAN aggregated traffic



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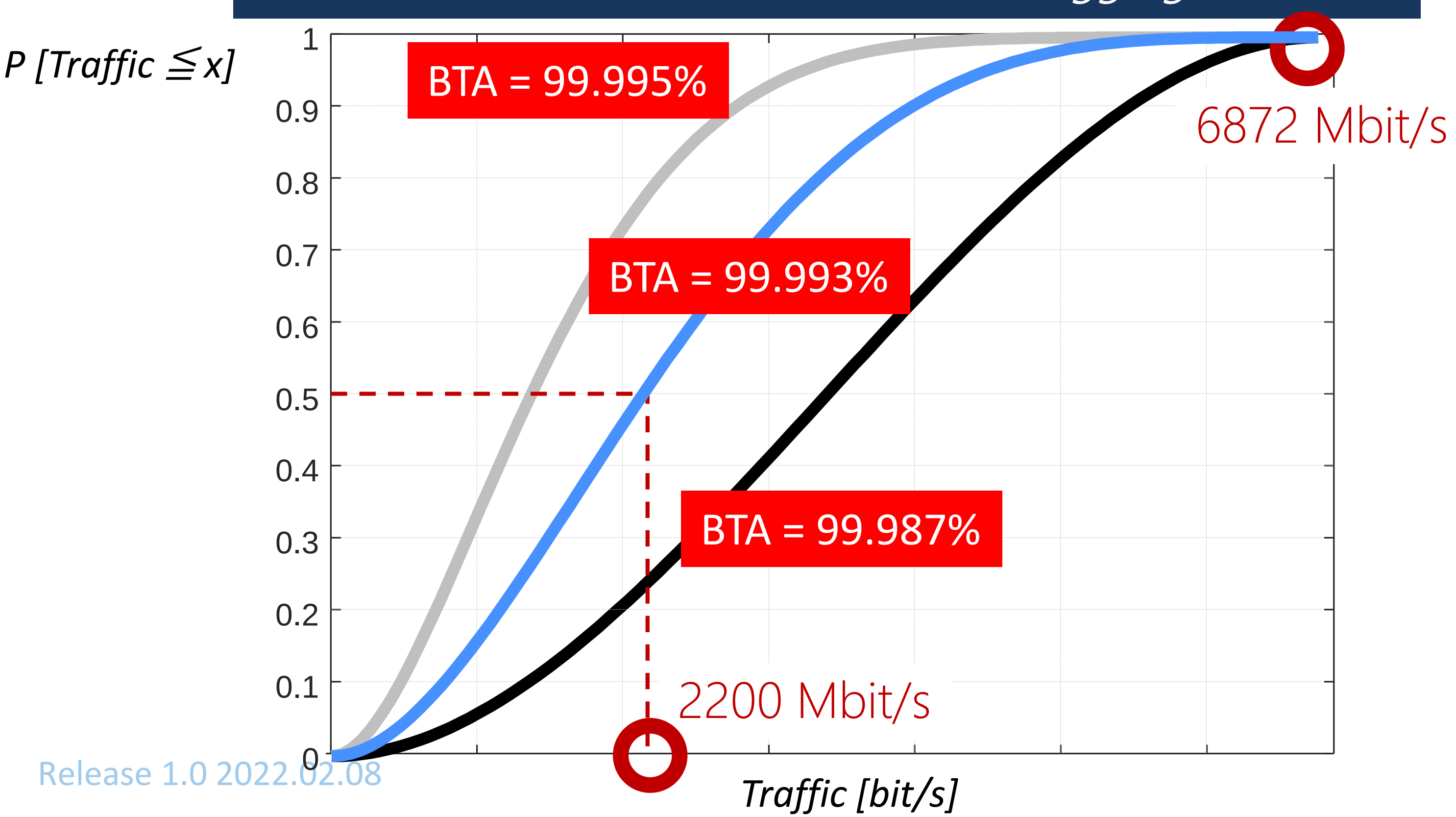

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E-band 500 MHz Dual Pol, 60 cm antennas *(42 mm/h)*

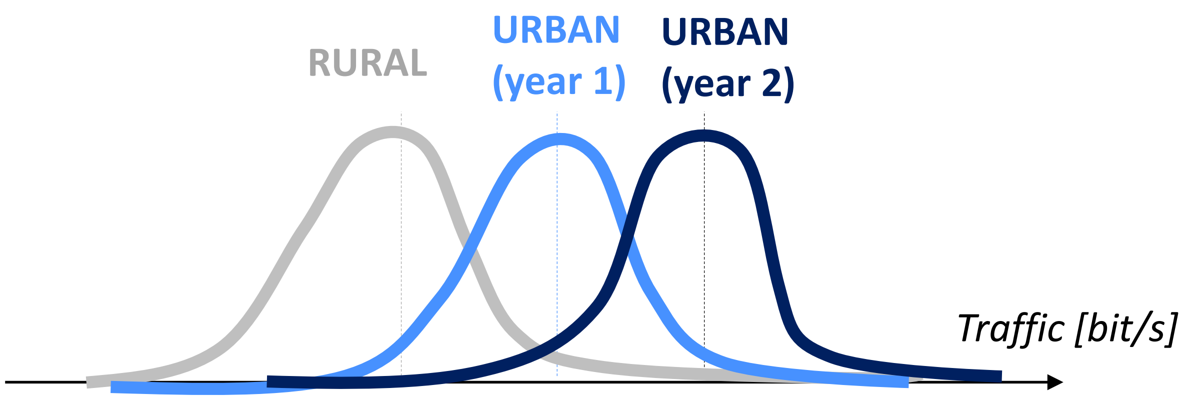
762 Mbit/s	1526 Mbit/s	2289 Mbit/s	3053 Mbit/s	3817 Mbit/s	4580 Mbit/s	5344 Mbit/s	6108 Mbit/s	6872 Mbit/s
99,998 %	99,996 %	99,994 %	99,993 %	99,991 %	99,986 %	99,980 %	99,975 %	99,957 %

E-band @ 4 km

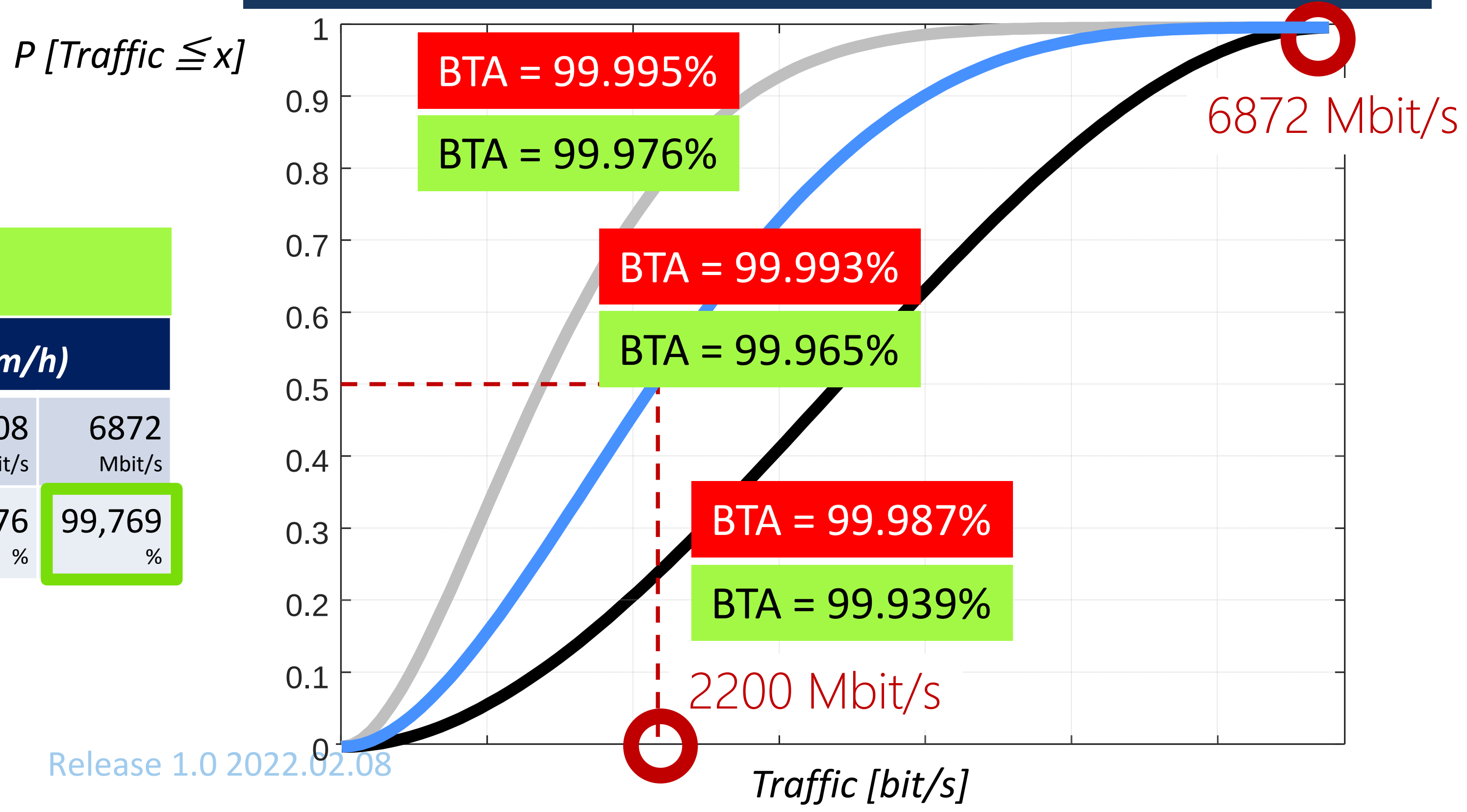
E-band 500 MHz Dual Pol, 60 cm antennas *(42 mm/h)*

762 Mbit/s	1526 Mbit/s	2289 Mbit/s	3053 Mbit/s	3817 Mbit/s	4580 Mbit/s	5344 Mbit/s	6108 Mbit/s	6872 Mbit/s
99,989 %	99,980 %	99,971 %	99,966 %	99,956 %	99,936 %	99,903 %	99,876 %	99,769 %

Probability density function of RAN aggregated traffic



Cumulative distribution function of RAN aggregated traffic



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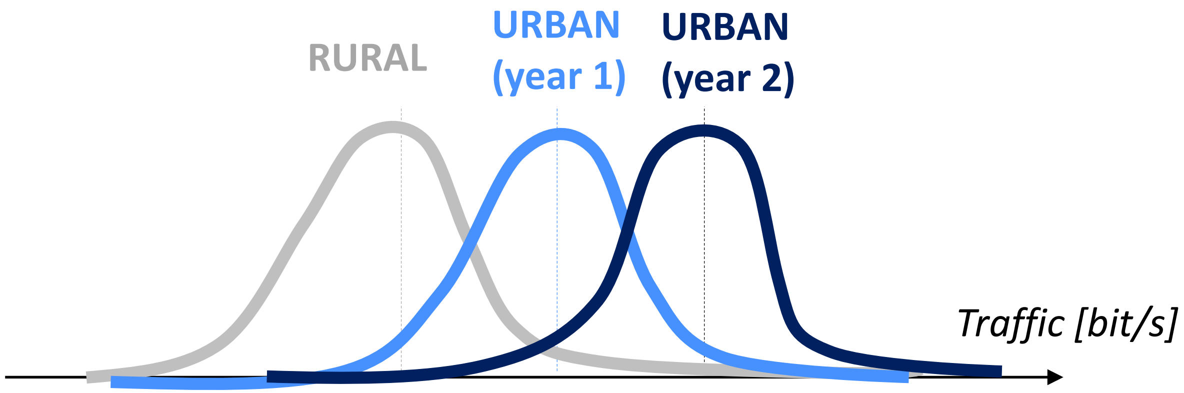
BTA & Traffic Statistics

E-band @ 2 km								
E-band 500 MHz Dual Pol, 60 cm antennas *(42 mm/h)*								
762 Mbit/s	1526 Mbit/s	2289 Mbit/s	3053 Mbit/s	3817 Mbit/s	4580 Mbit/s	5344 Mbit/s	6108 Mbit/s	6872 Mbit/s
99,998 %	99,996 %	99,994 %	99,993 %	99,991 %	99,986 %	99,980 %	99,975 %	99,957 %

Probability density function of RAN aggregated traffic



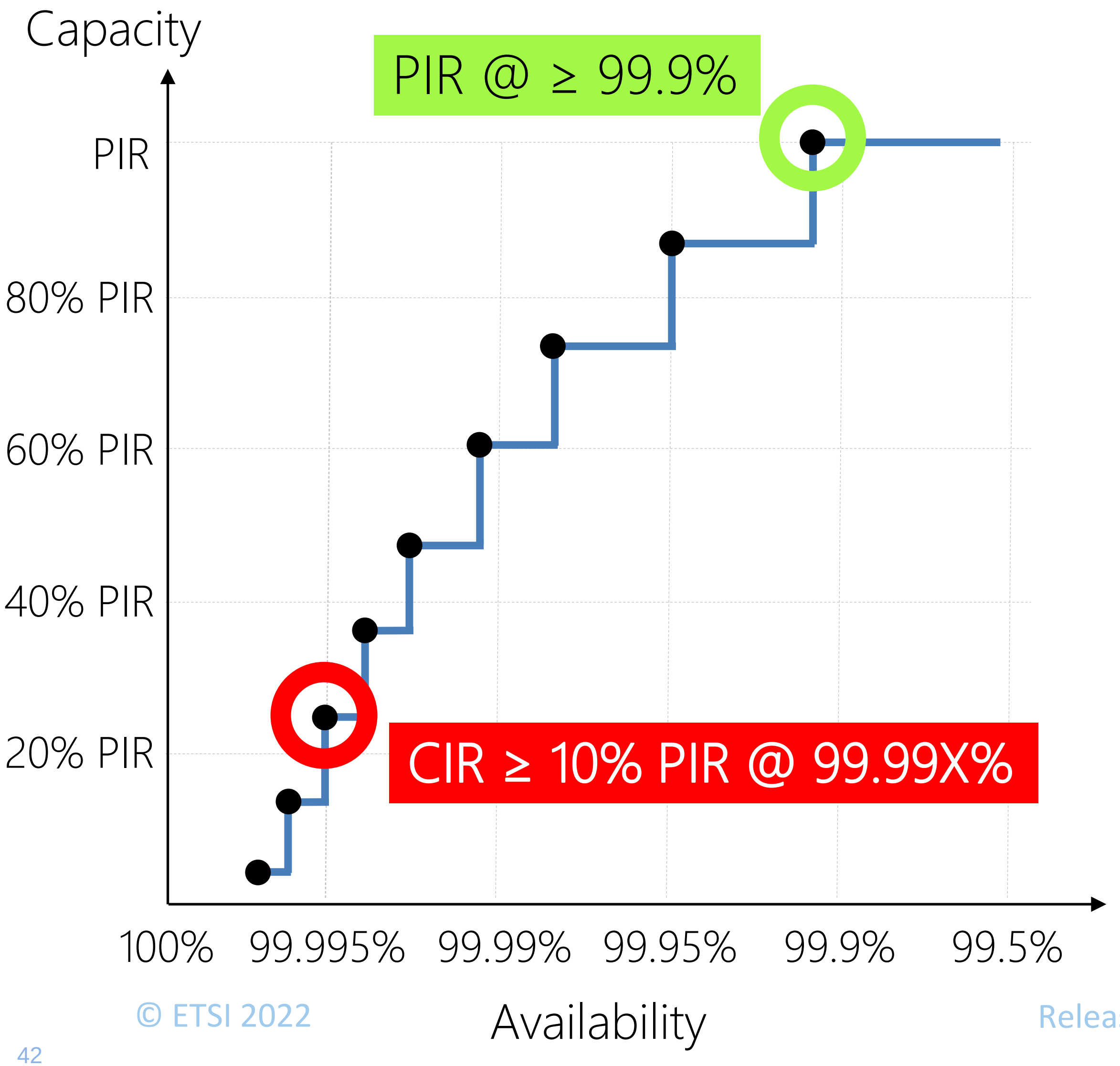
Cumulative distribution function of RAN aggregated traffic

- **BTA degradation** versus the extension of the link length does not scale linearly with PIR availability degradation, but **follows more the degradation of the link capacities between CIR and PIR**, according to the specific RAN traffic distribution
- This fact, in conjunction with End User Experience simulations results (presented in the following), clearly shows that **MW/mmWave Backhaul maximum link distances can be stretched much more** than current best practices adopted by MNOs (e.g., **2km** for a stand alone **E-Band**, **7km** for BCA link with **E-Band**)
- It is possible to **increase the use of spectrum in the mmWave range** (both stand-alone and BCA) with all related **TCO advantages** (lower spectrum cost and less MW/mmWave radios to be deployed) and by avoiding low-bands spectrum congestion risks

Content

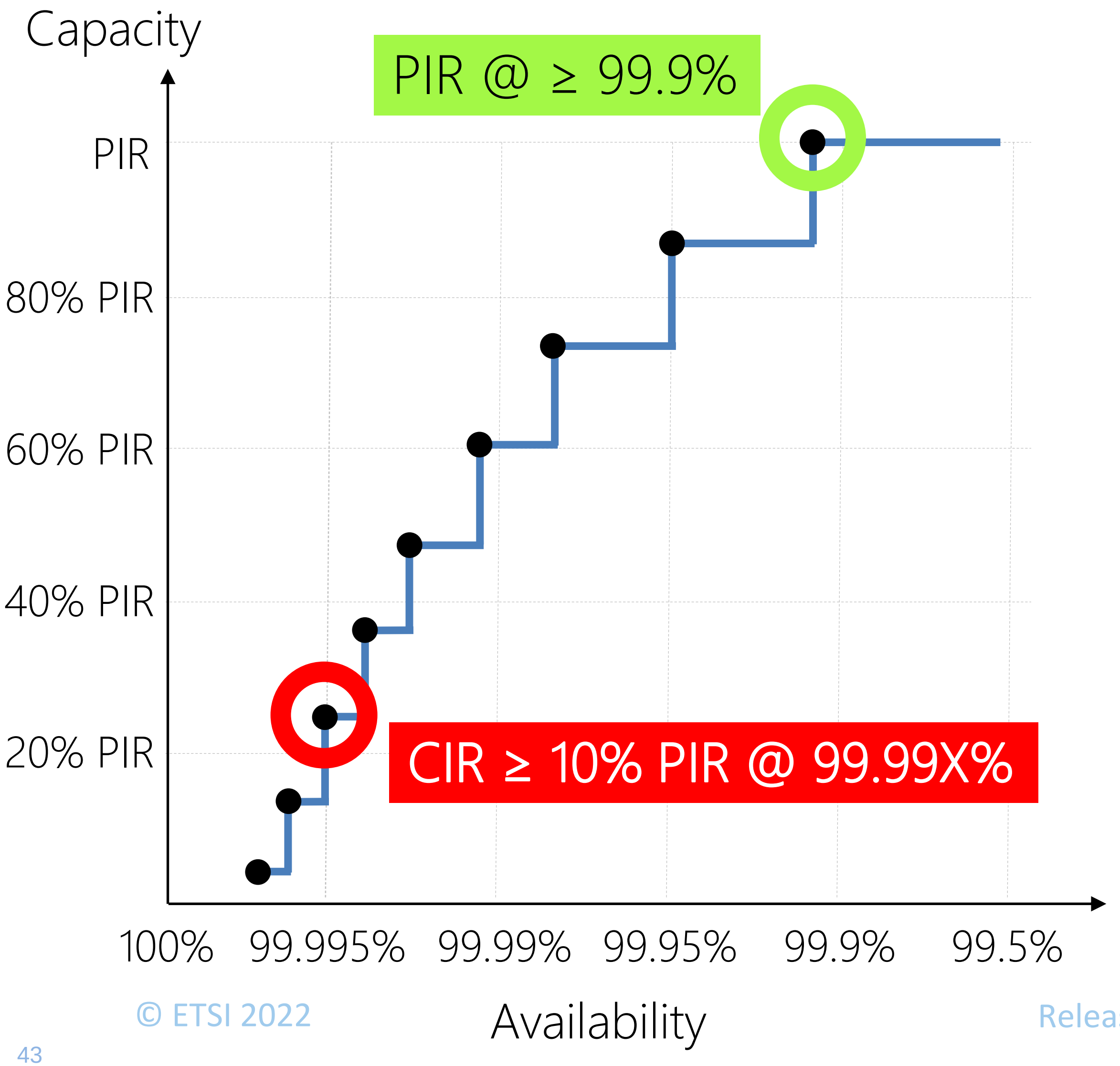
Towards a 3 Check Points Planning Method

Current 2 Check Points Planning

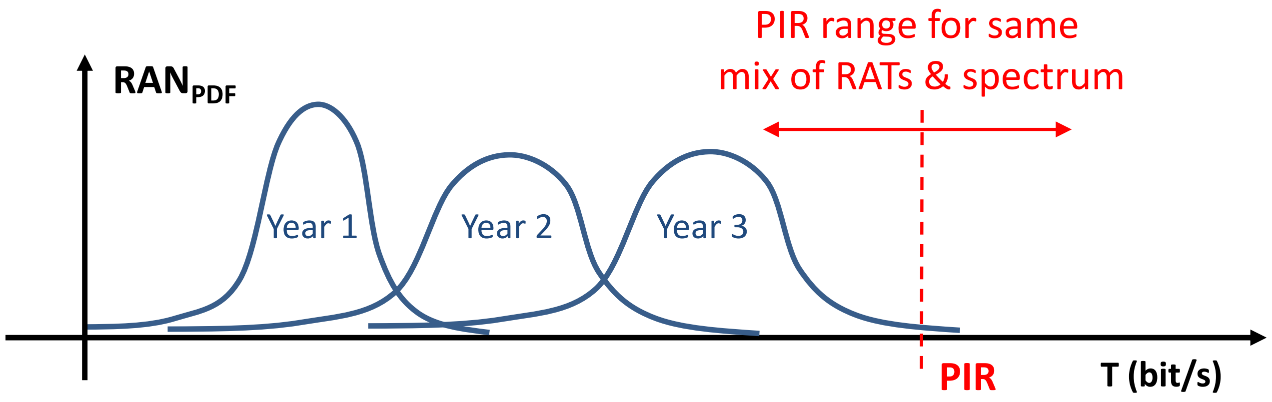


Towards a 3 Check Points Planning Method

Current 2 Check Points Planning



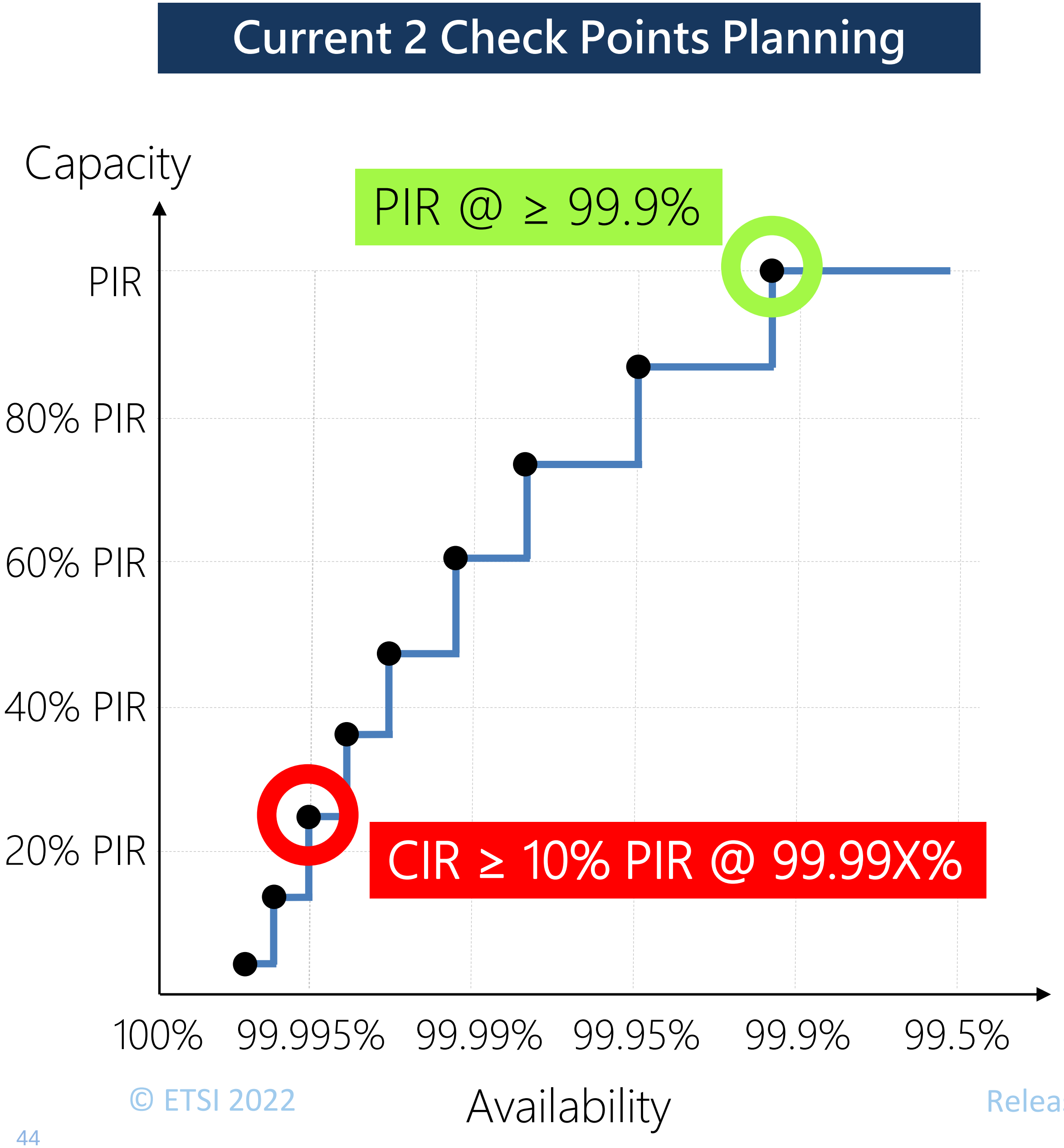
PIR is often calculated with **closed-form formulas** depending on the specific **RATs** employed



Limits:

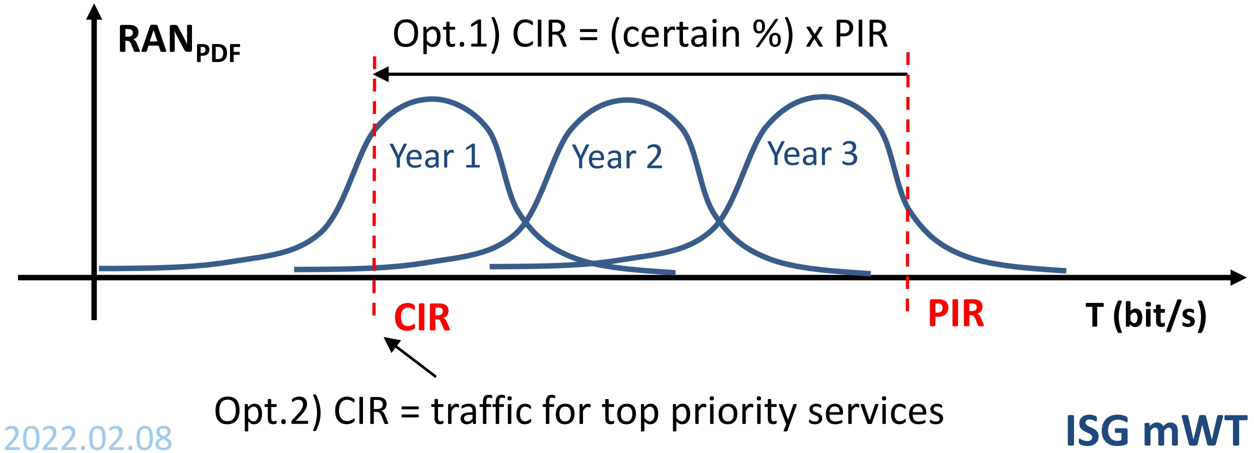
- PIR **might be never impacting** RAN traffic (e.g., if PIR is calculated as the sum of peaks of all RAT layers)
- No clear relationship between actual End User Experience and PIR target requirements

Towards a 3 Check Points Planning Method

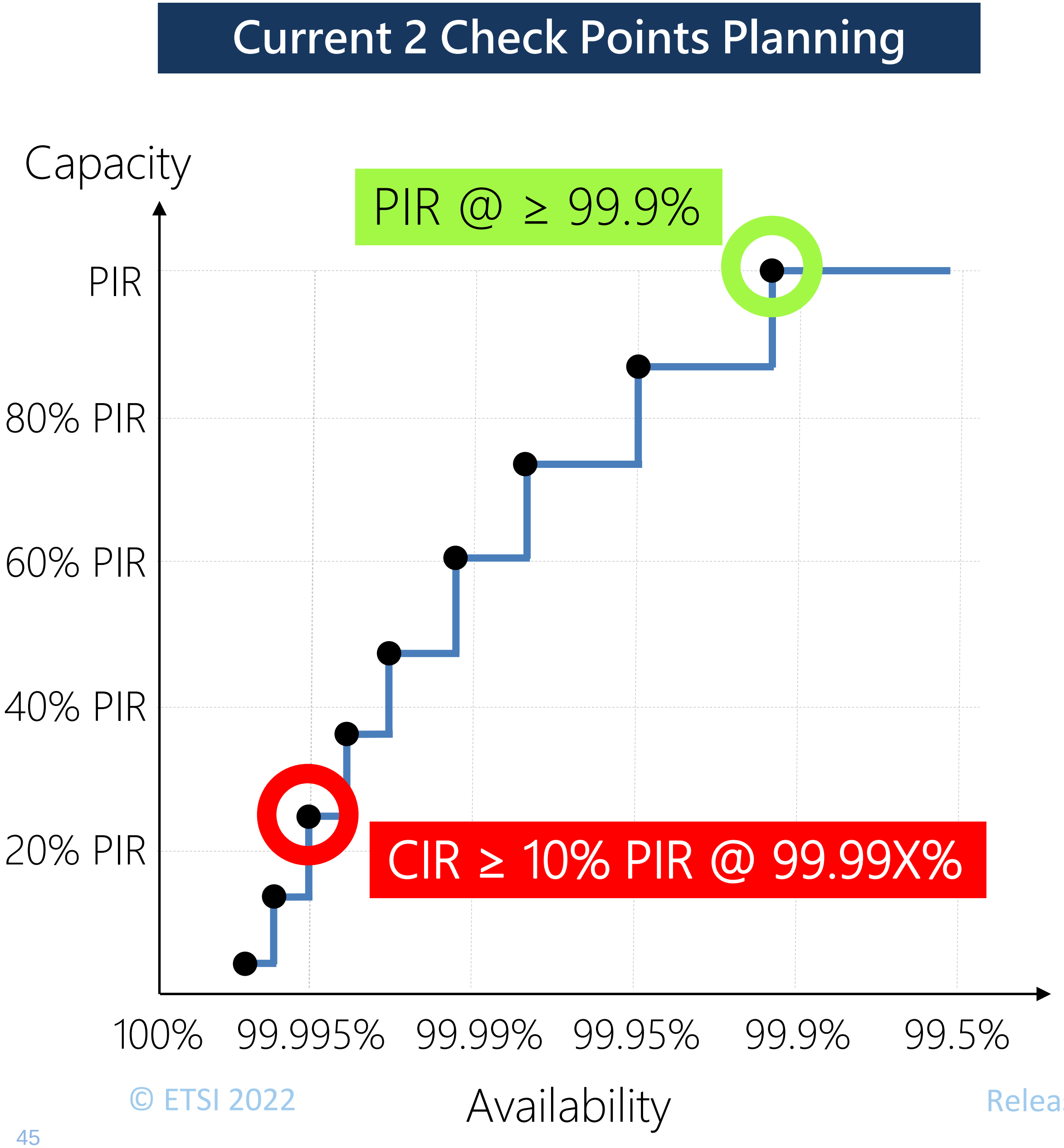


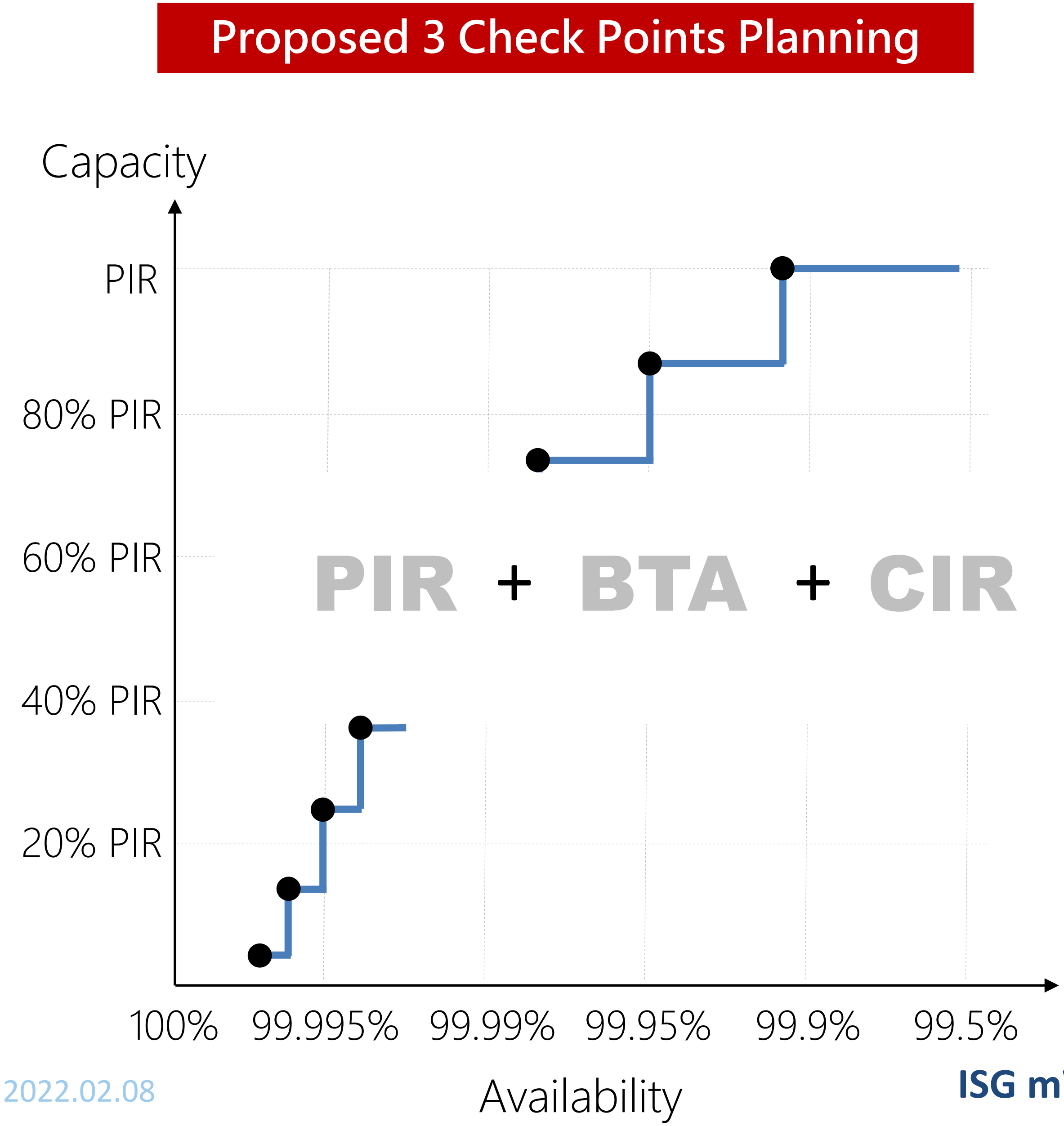
CIR is even more **disconnected** from data traffic delivery and user experience

- from 2G to 3G era CIR was associated to minimum link capacity to be delivered with voice services availability
- with **4G** and **beyond** CIR started to **follow the evolution of PIR**, maintaining very high target availability (4 to 5 nines) and becoming the **most stringent link design criteria** in most cases



Towards a 3 Check Points Planning Method



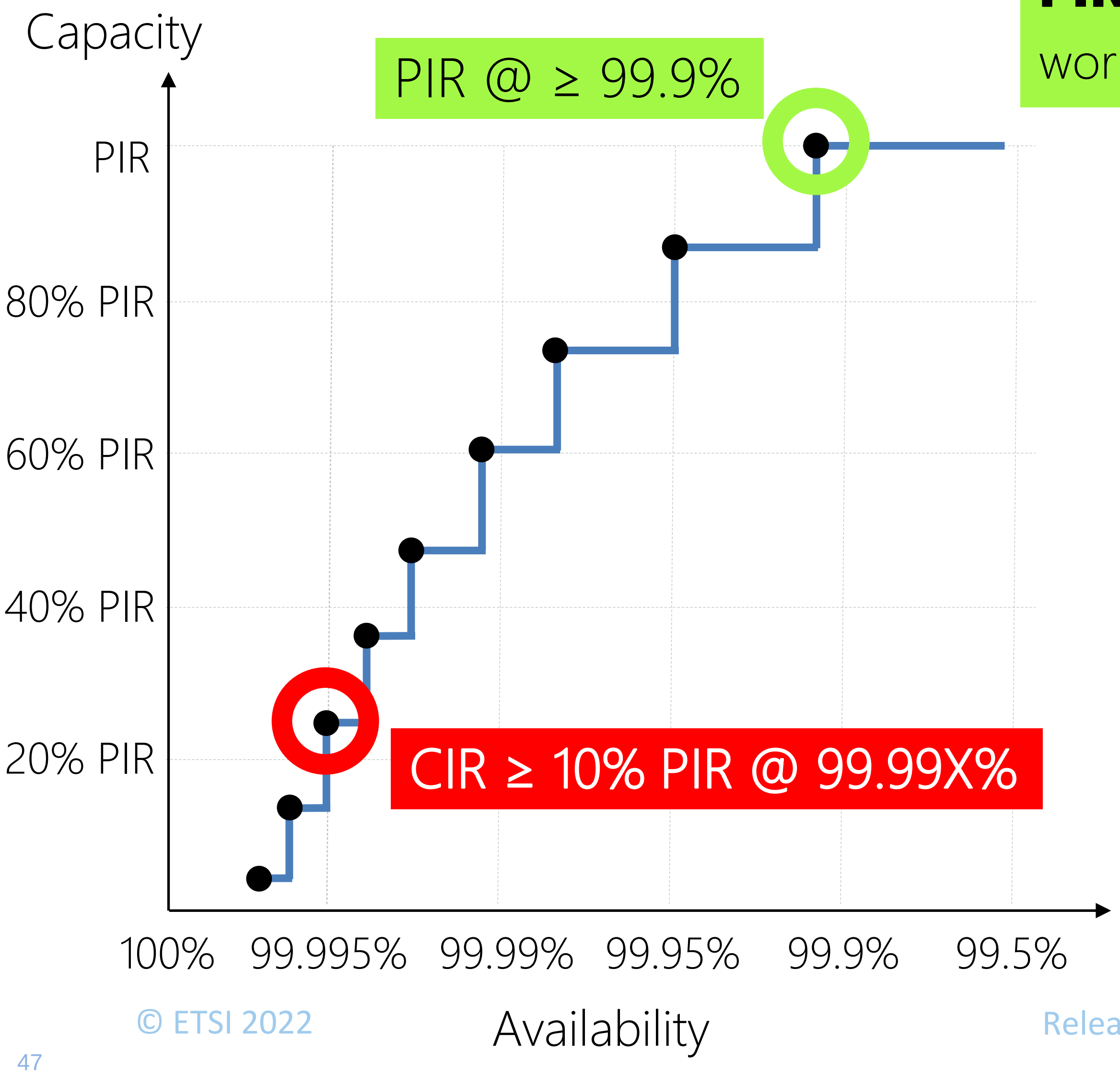


Content

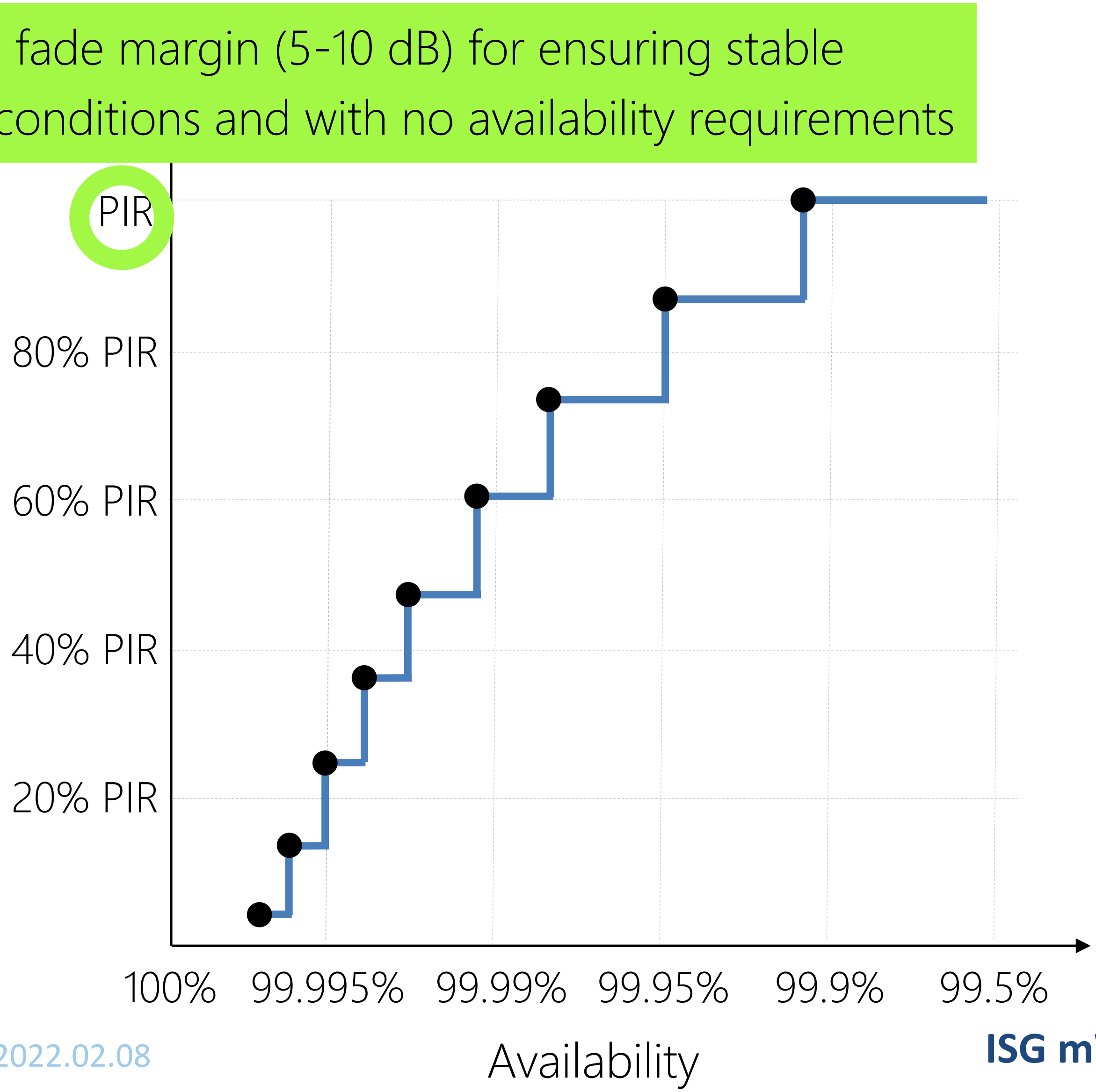
- Introduction Of ISG mWT
- Rationale For New KPIs To Evaluate Wireless Backhaul Performance
  - Background And Overview
  - Current Planning
  - Statistical Nature Of RAN Traffic
  - Definition Of BTA – Backhaul Traffic Availability
- Towards a 3 Check Points Planning Method
  - PIR + BTA + CIR
  - Planning Examples
- Planning & Measuring BTA In Live Networks
- Conclusions & Future Work

Towards a 3 Check Points Planning Method

Current 2 Check Points Planning



Proposed 3 Check Points Planning



Towards a 3 Check Points Planning Method

Current 2 Check Points Planning

Proposed 3 Check Points Planning

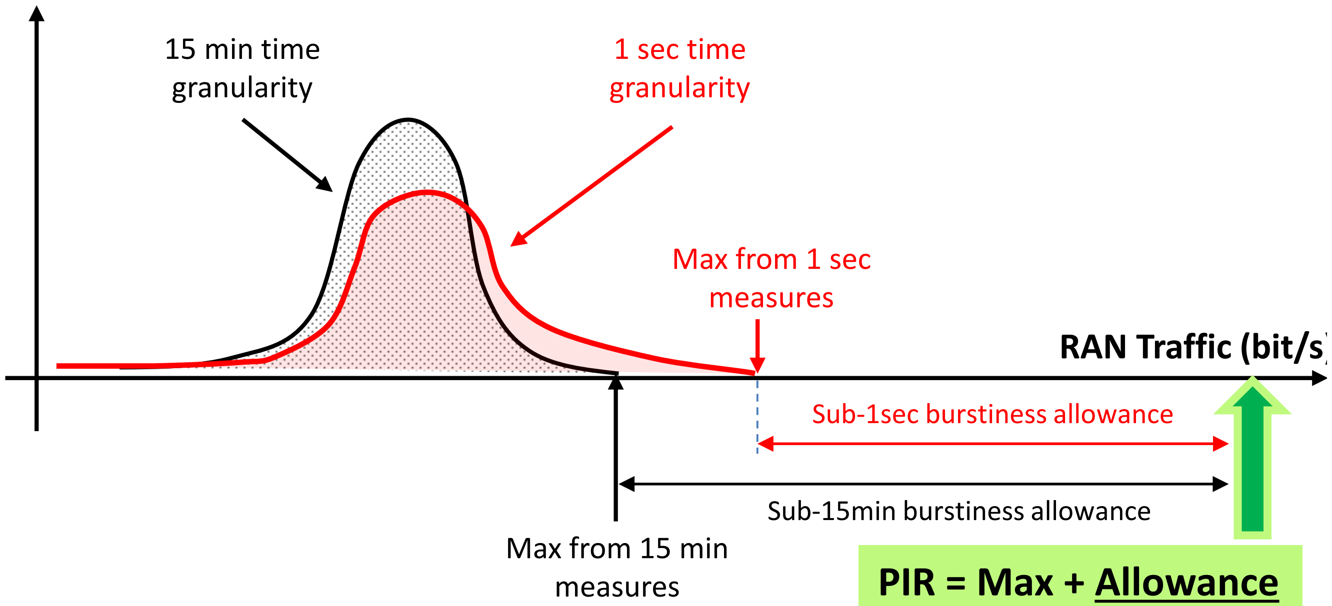
PIR with fade margin (5-10 dB) for ensuring stable working conditions and with no availability requirements

Capacity

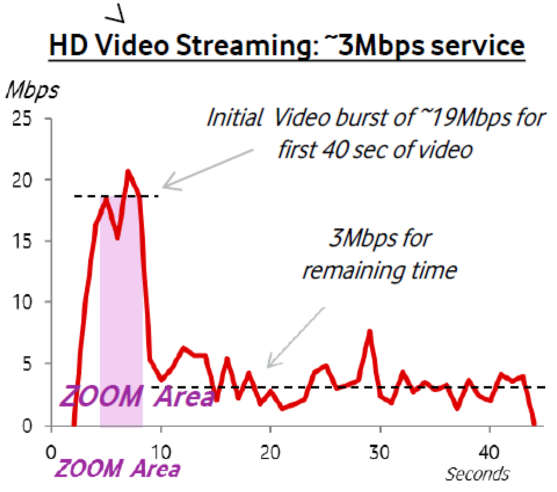
PIR @ ≥ 99.9%

PIR should be designed to **accommodate** sub-second data **burstiness** that may not be captured by the available RAN traffic statistics (<u>notice</u>: when PIR is not available there might be a slight latency increase but all RAN traffic will be delivered)

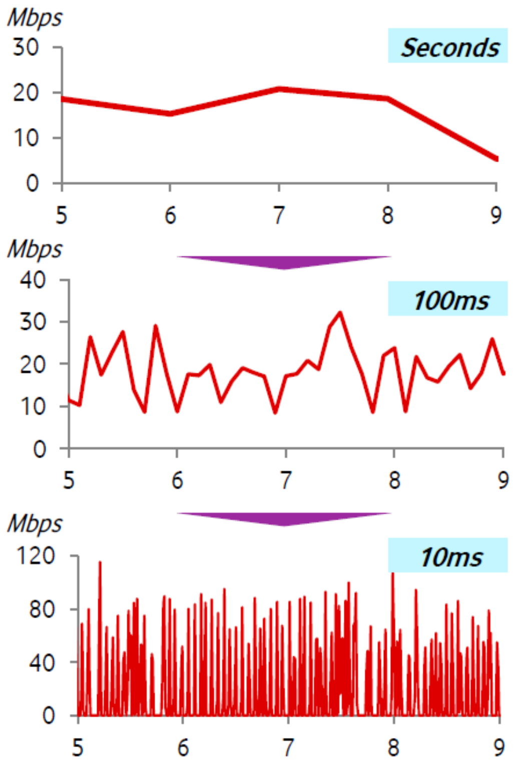
Traffic has **strong burstiness** if observed with time granularity < 1 s



PIR = Max + <u>Allowance</u>



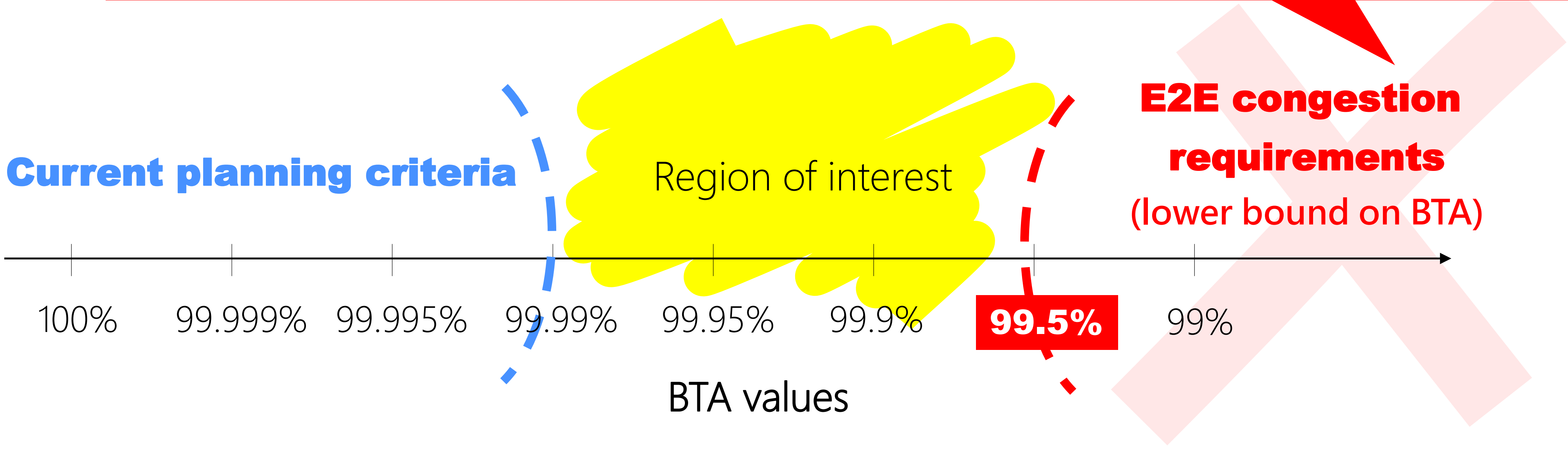
Analysis performed on unloaded 20MHz LTE 2600 site with device limited to 100Mbps



Content

Target BTA

MNOs can define **minimum BTA targets** by **allocating** a certain congestion probability (from overall network E2E congestion probability) to MW/mmWave Backhaul links



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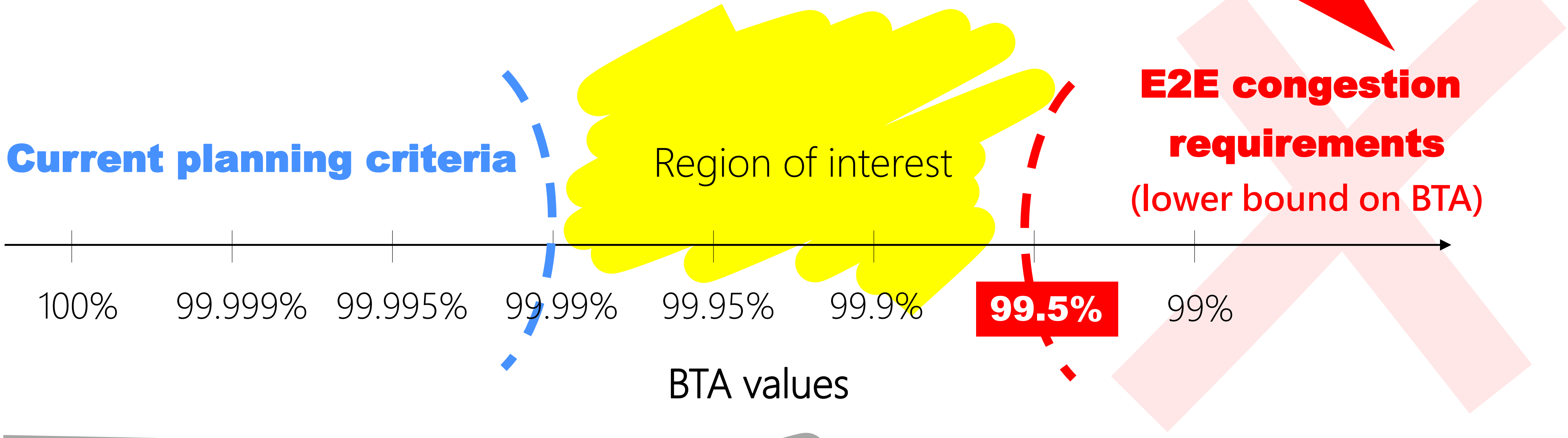


Massive simulation campaigns to:

1) connect **BTA** to **End User Experience**

2) determine the target **BTA range**

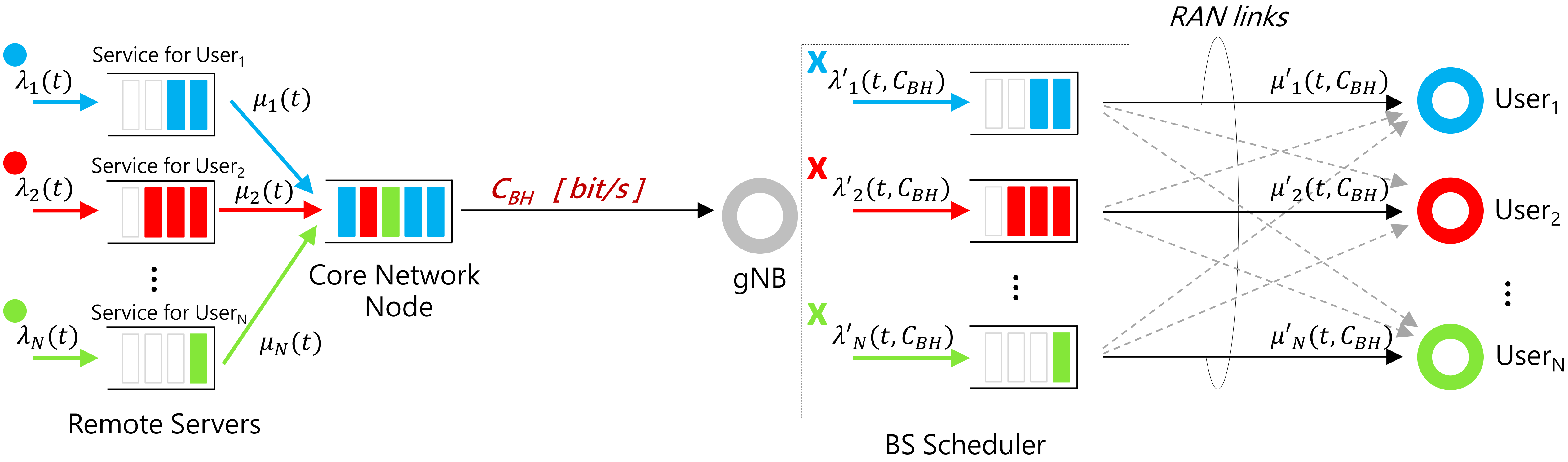
1st Simulation Campaign

250 MHz E-band Backhaul Link

One 5G RAN site

3GPP-based Virtual Reality, Cloud Gaming & FTP traffic models

Adopted Network Simulation Setup (Constrained BH)



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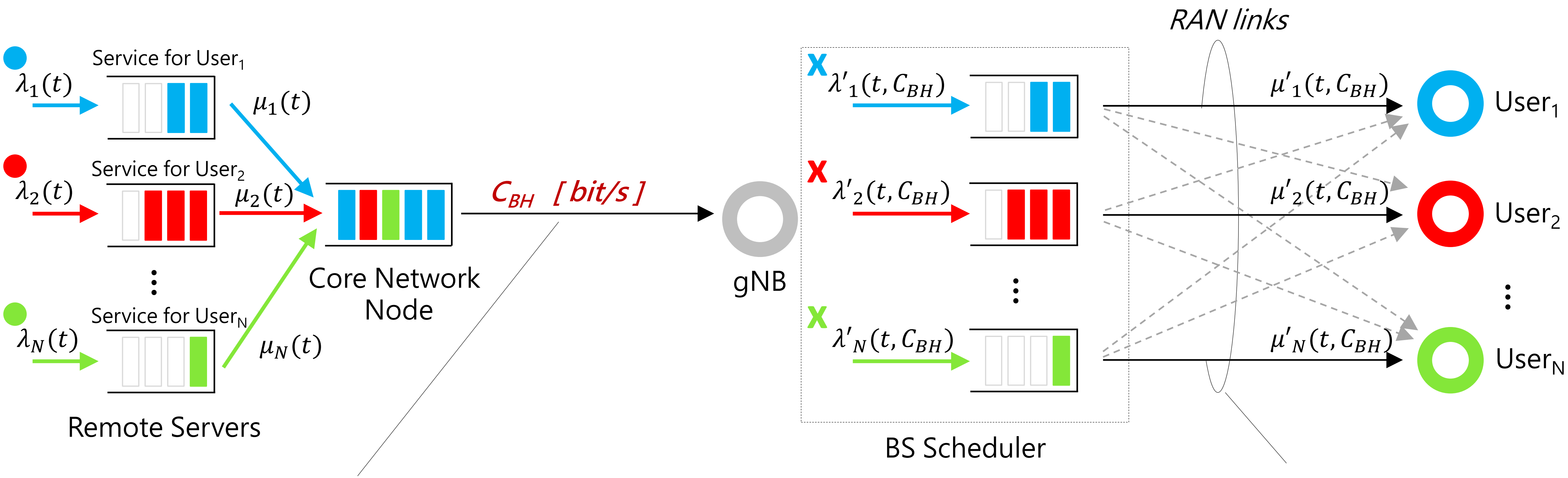


E-band Backhaul link

Single Polarization, 250 MHz

C_{BH} ∊ [189, 379, 569, 759, 949, 1139, 1329, 1519, 1708, 1803] Mbit/s

Virtually infinite buffer lengths

5G New Radio Cellular Network (3.5 GHz)

Bandwidth = 100 MHz

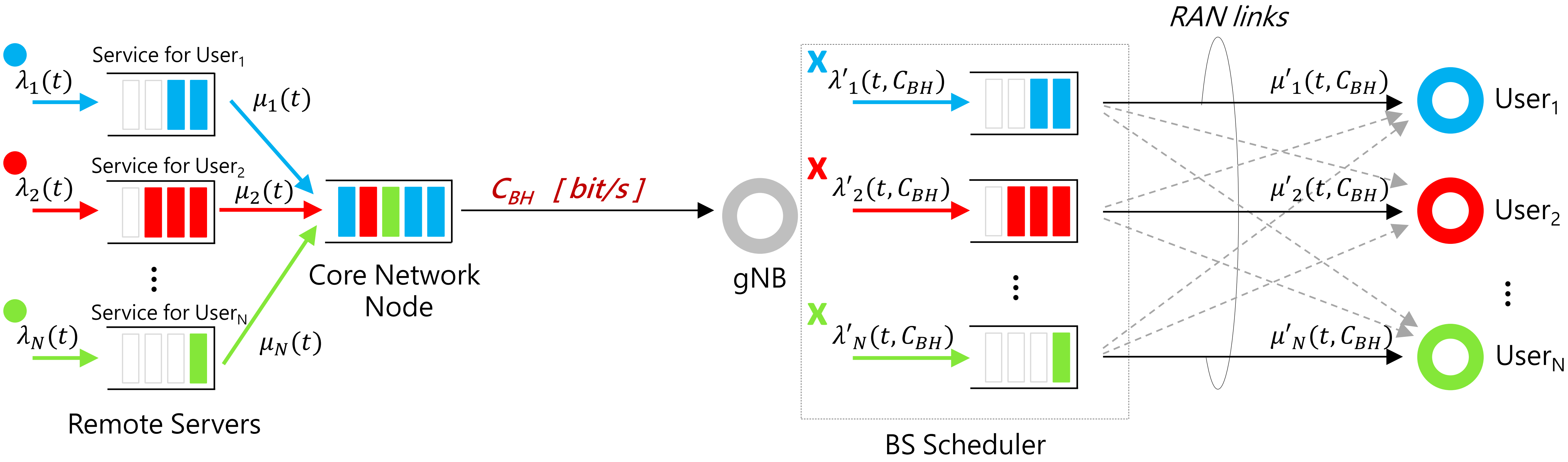
Total number of cells = 1

Total number of sectors = 3

DL/UL ratio = 4:1

3GPP TR 38.901 channel model

Adopted Network Simulation Setup (Constrained BH)



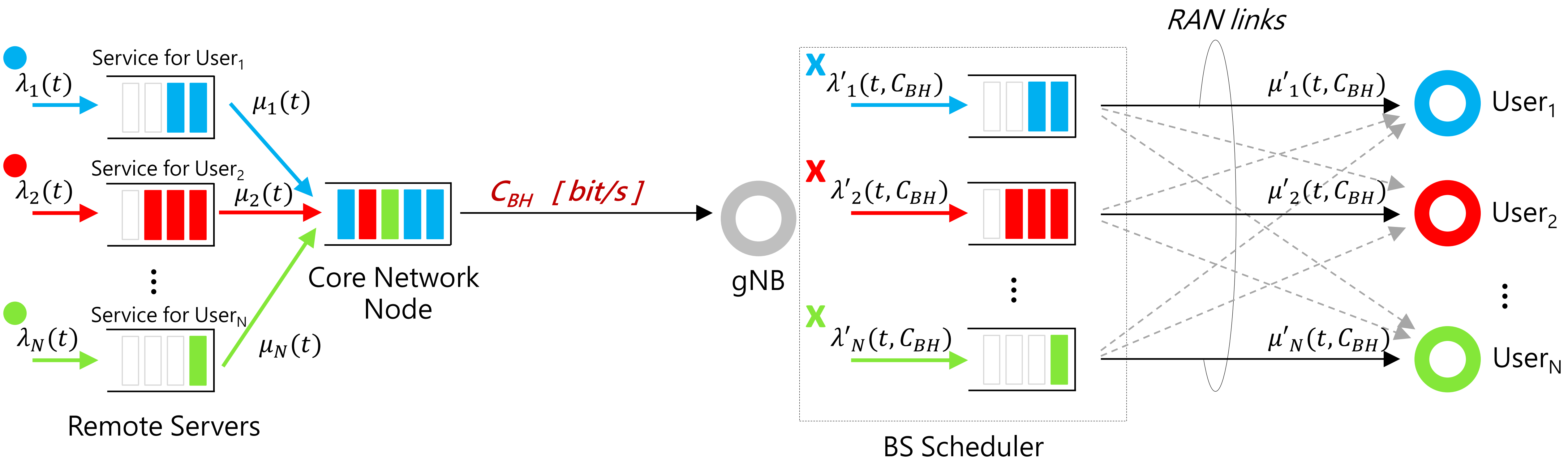
Advantages

- The proposed approach is able to capture congestion phenomena occurring over both RAN and Backhaul

Assumptions

- **No traffic congestion management mechanisms** / queue admission control policies (provided by higher level protocols) are implemented here (**conservative choice**)

Adopted Network Simulation Setup (Constrained BH)

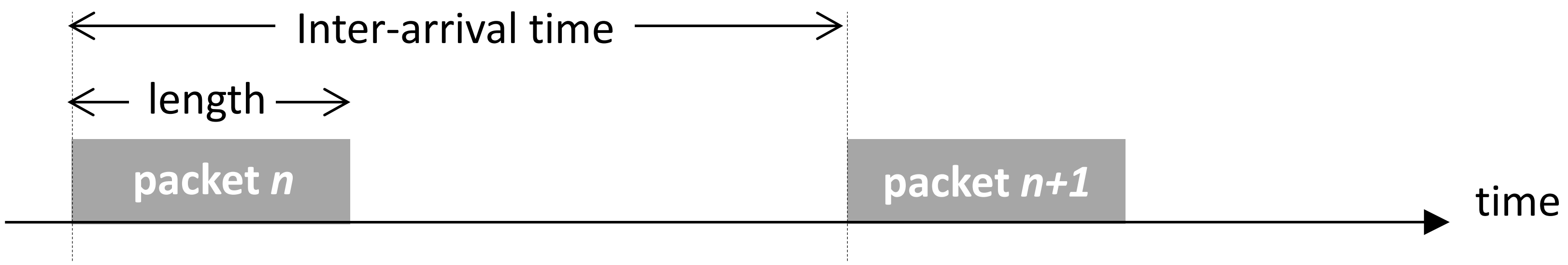


Important KPI

- Packet latency = latency over BH link + latency over RAN

Scenario 1

SOURCE: Huawei



100 % UEs run Virtual Reality

		Packet Generation Rate (F)	Average Data Rate (R)	Packets Length	Packets Inter-arrival Time	REQUIREMENTS FOR HAPPY USER		Source
						Packet Delay Budget	Packet Success Rate	
				Mbit	s	[ms]	[%]	
100 %	VR (DL)	60	30	Truncated Gaussian random variable (with mean R/F Mbit)	1/F + Truncated Gaussian random variable (with mean 0 ms)	10	99	3GPP TR 38.838 V17.0.0

Scenario 1

SOURCE: Huawei

<u>5G New Radio Cellular Network (3.5 GHz)</u>

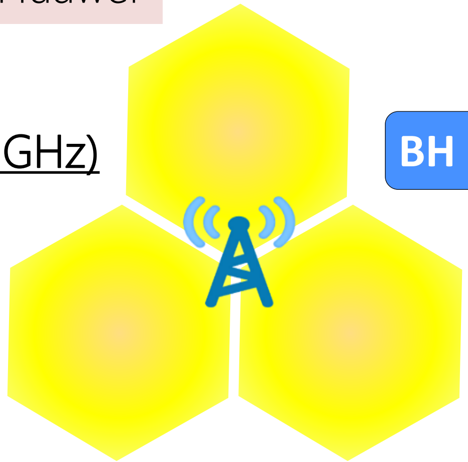
Bandwidth = 100 MHz

1 radio site, 3 sectors (165m radius)

DL/UL ratio = 4:1

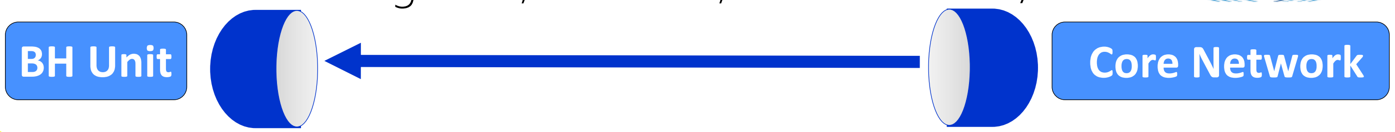
3GPP TR 38.901 channel model

Max number of users = **51** (peak traffic = **1754** Mbit/s)



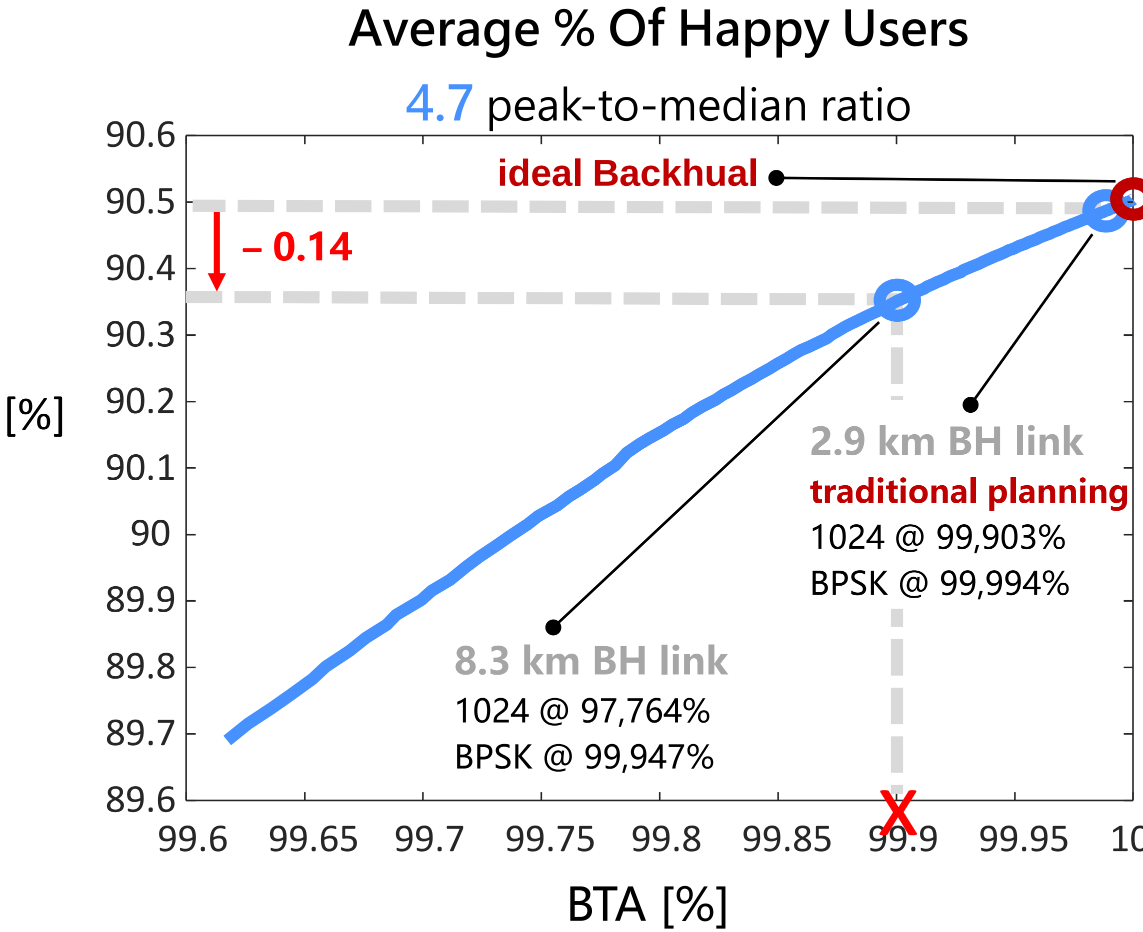
<u>E-band (60 mm/h rain rate)</u>

Single Pol, 250 MHz, max 1803 Mbit/s



100% UEs run 30 Mbit/s Virtual Reality service

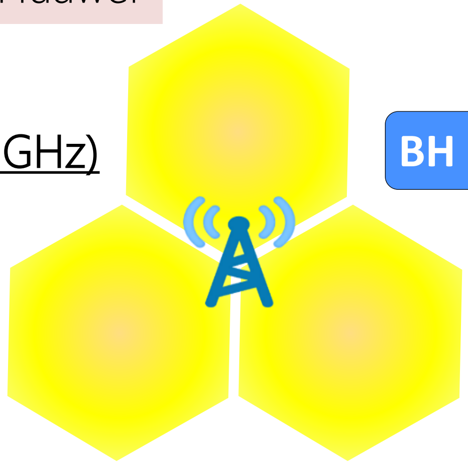
Happy user if **99** % packets have latency < **10** ms



A BTA requirement of <u>**~ 99.9%**</u> may **at least <u>DOUBLE</u>** the achievable distance (with respect to current criteria) in many <u>**E-band / BCA**</u> scenarios, with a <u>**negligible impact**</u> on the Avg % Of <u>**Happy Users**</u>

Scenario 1

SOURCE: Huawei



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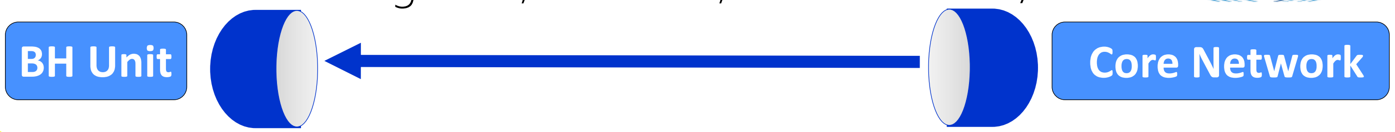


5G New Radio Cellular Network (3.5 GHz)

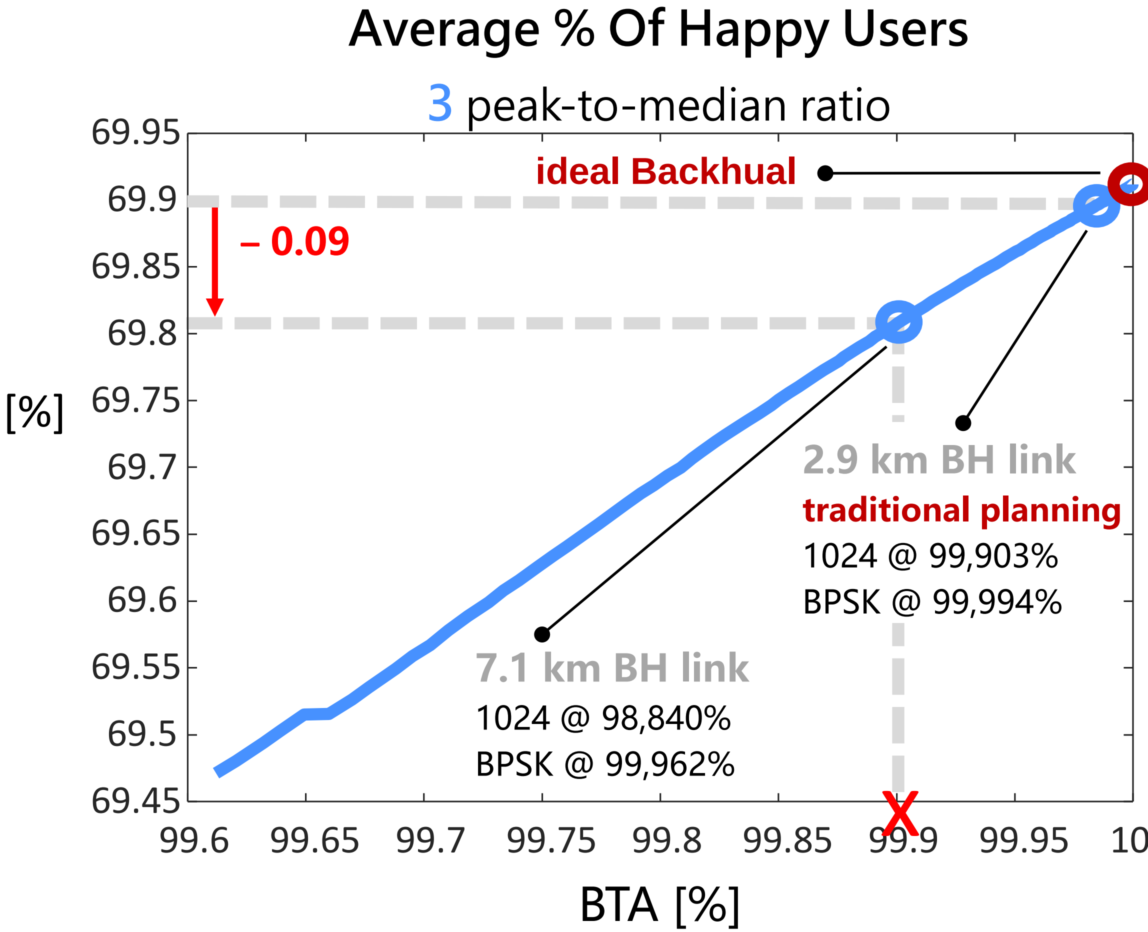
Bandwidth = 100 MHz

1 radio site, 3 sectors (165m radius)

DL/UL ratio = 4:1

3GPP TR 38.901 channel model

Max number of users = **51** (peak traffic = **1822** Mbit/s)



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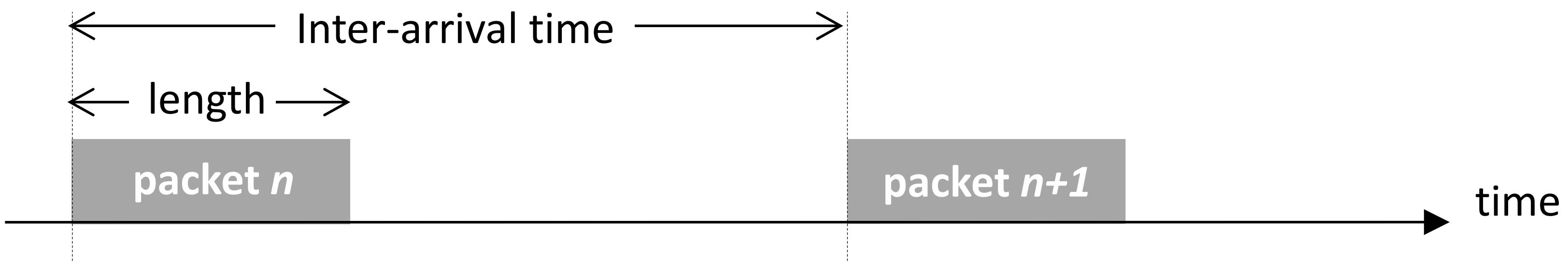
A BTA requirement of **~ 99.9%** may **at least DOUBLE** the achievable distance (with respect to current criteria) in many **E-band / BCA** scenarios, with a **negligible impact** on the Avg % Of **Happy Users**

Scenario 2

SOURCE: Huawei



		Packet Generation Rate (F)	Average Data Rate (R)	Packets Length	Packets Inter-arrival Time	REQUIREMENTS FOR HAPPY USER		Source
						Packet Delay Budget	Packet Success Rate	
		[Hz]	[Mbit/s]	Mbit	s	[ms]	[%]	
67 %	VR (DL)	60	30	Truncated Gaussian random variable (with mean R/F Mbit)	1/F + Truncated Gaussian random variable (with mean 0 ms)	5, 10, 20, 30	95, 99, 99.5, 99.9, 99.95	3GPP TR 38.838 V17.0.0
33 %	FTP (DL)	-	-	4	Exponentially distributed random variable (mean = 5 s)	600	100	3GPP TR 36.814 V9.2.0

SOURCE: Huawei

(a) **Average % Of Happy Users**

Backhaul link length = 0 km, BTA = 99.997 % (*)

Packet Delay Budget

Packet Success Rate	5 ms	10 ms	20 ms	30 ms
95 %	13,097 %	44,082 %	56,826 %	63,103 %
99 %	3,007 %	32,497 %	51,591 %	58,910 %
99.5 %	1,549 %	28,755 %	49,668 %	56,694 %
99.9 %	0,238 %	15,457 %	43,788 %	53,072 %
99.95 %	0,033 %	11,751 %	41,679 %	51,193 %

(*) BTA @ 0 km is determined by the probability that RAN traffic > BH PIR

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(b) Drop in Average % Of Happy Users with respect to (a) in percentage points

Backhaul link length = 2.9 km, BTA = 99.983 %

traditional planning

Packet Delay Budget

Packet Success Rate	5 ms	10 ms	20 ms	30 ms
95 %	0,003	0,008	0,010	0,011
99 %	0,001	0,006	0,009	0,010
99.5 %	0,000	0,006	0,008	0,009
99.9 %	0,000	0,004	0,007	0,009
99.95 %	0,000	0,003	0,008	0,008

(c) Drop in Average % Of Happy Users with respect to (a) in percentage points

Backhaul link length = 7.5 km, BTA = 99.9 %

Packet Delay Budget

Packet Success Rate	5 ms	10 ms	20 ms	30 ms
95 %	0,026	0,055	0,069	0,078
99 %	0,006	0,039	0,061	0,072
99.5 %	0,003	0,044	0,058	0,059
99.9 %	0,001	0,030	0,042	0,061
99.95 %	0,000	0,027	0,056	0,057

- **60 mm/h** rain rate, **3.5** peak-to-median ratio
- Max number of users = **90** (peak traffic = **2** Gbit/s)
- Drop in Average % of Happy Users is **< 0.01** percentage points from **0 km to 2.9 km**, and **< 0.07** percentage points from **2.9 km to 7.5 km**

(*) BTA @ 0 km is determined by the probability that RAN traffic > BH PIR

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(*) BTA @ 0 km is determined by the probability that RAN traffic > BH PIR

2nd Simulation Campaign

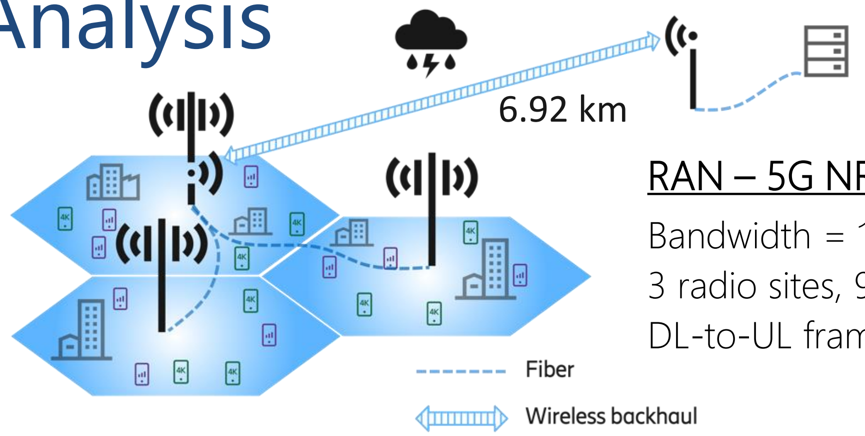
BCA Backhaul Link (E-band + 18 GHz)

Three 5G RAN sites

Realistic HD video and web browsing models

Analysis

SOURCE: Ericsson



Backhaul (35 mm/h rain rate)

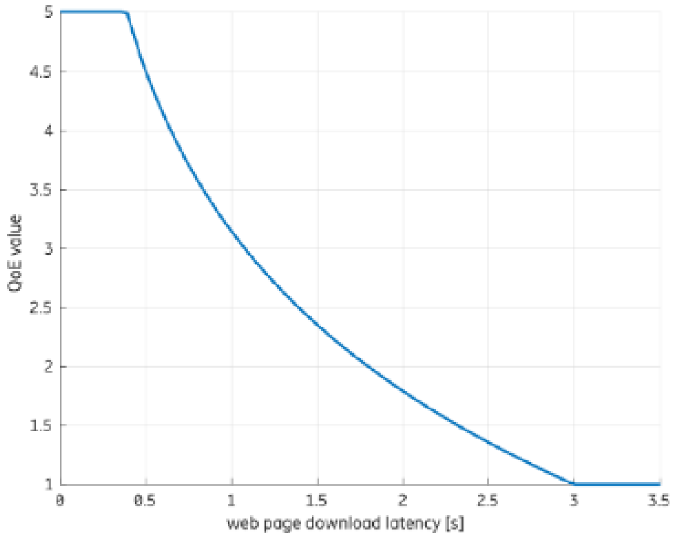
E-band (750 MHz, ACM) + 18 GHz (56 MHz, ACM)
6.92 km, peak rate = 3.58 Gbit/s

RAN – 5G NR

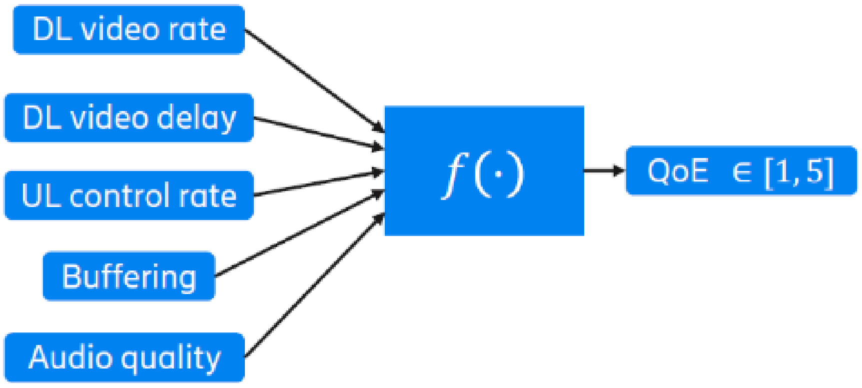
Bandwidth = 100 MHz (@ 3.5GHz)
3 radio sites, 9 sectors, ISD = 500 m
DL-to-UL frame ratio = 3:2

QoE measurement criteria

Web browsing: download time for a 2MB file

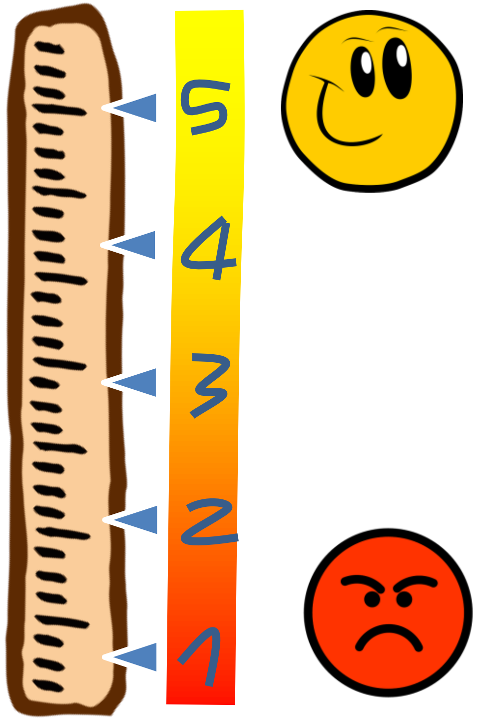


Video on-demand: DL streaming of HD video



QoE ∈ [1,5] measured according to ITU-T P.1203

QoE & **User Happiness**

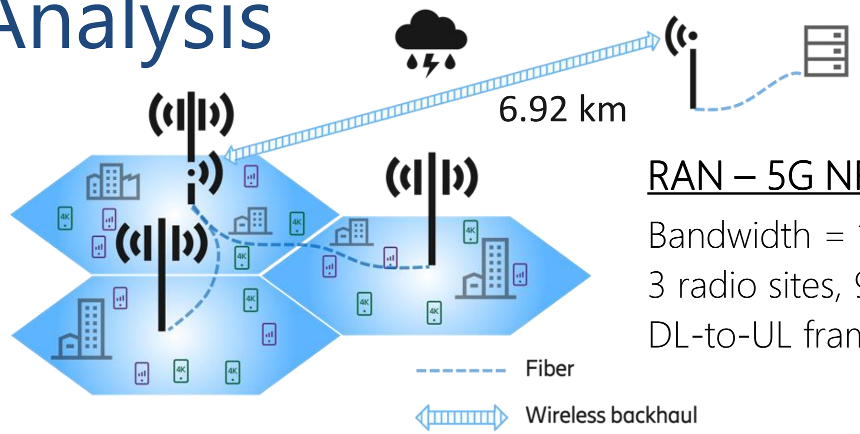


Release 1.0 2022.02.08

ISG mWT

Analysis

SOURCE: Ericsson



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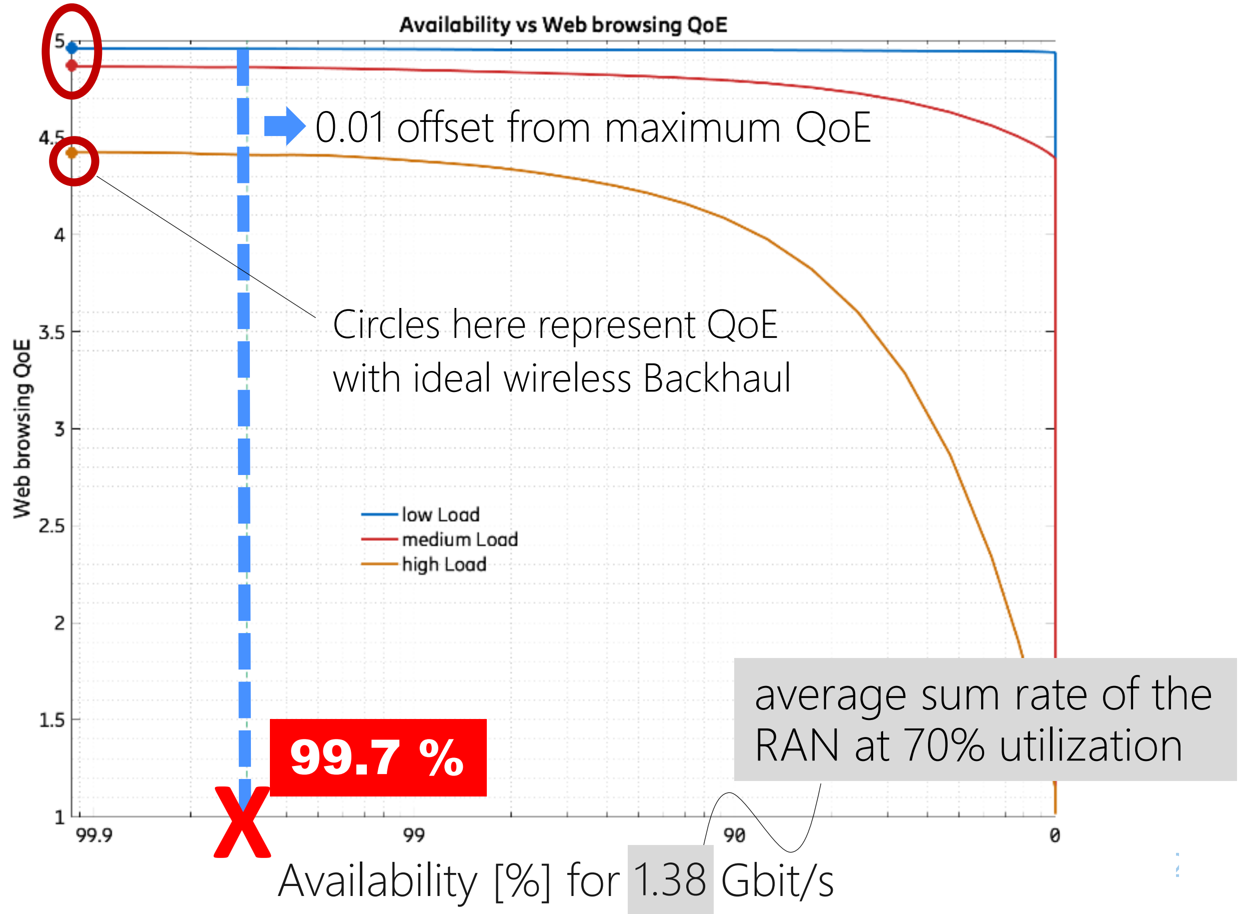
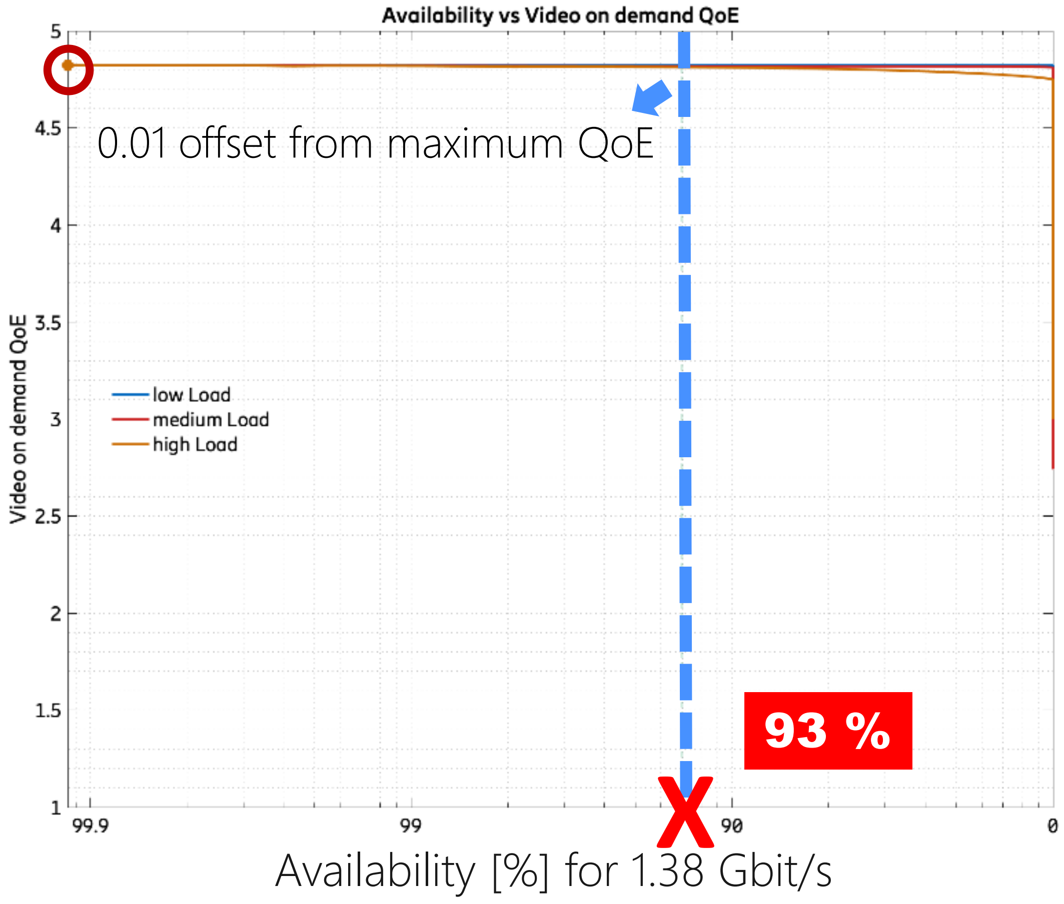
RAN – 5G NR
Bandwidth = 100 MHz (@ 3.5GHz)
3 radio sites, 9 sectors, ISD = 500 m
DL-to-UL frame ratio = 3:2

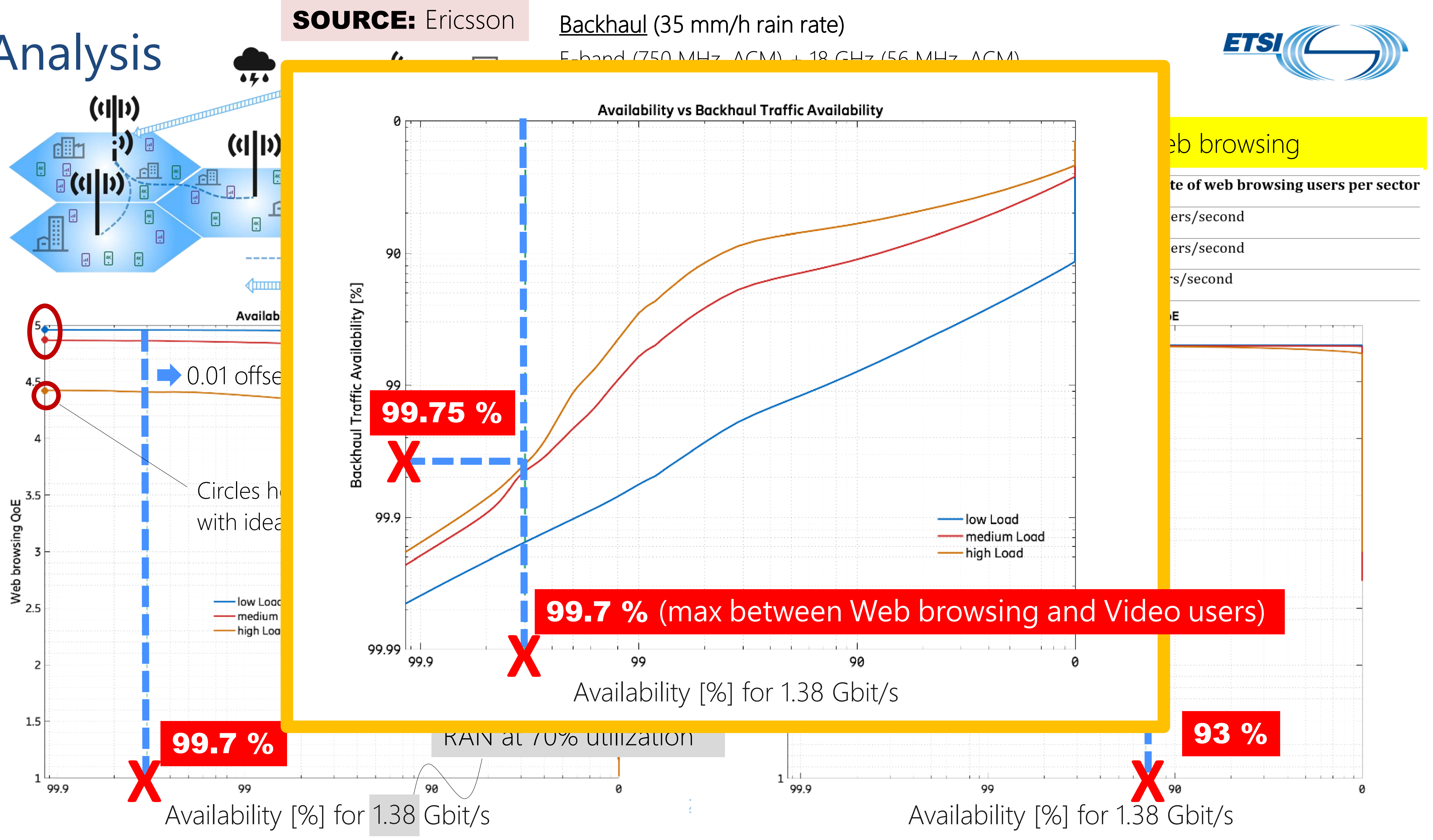
Mixed Traffic: 12 Mbit/s Video + Web browsing

Load level	# Video users per sector	Arrival rate of web browsing users per sector
Low load	3 video users	1.8 web users/second
Medium load	17 video users	2.2 web users/second
High load	22 video users	4 web users/second





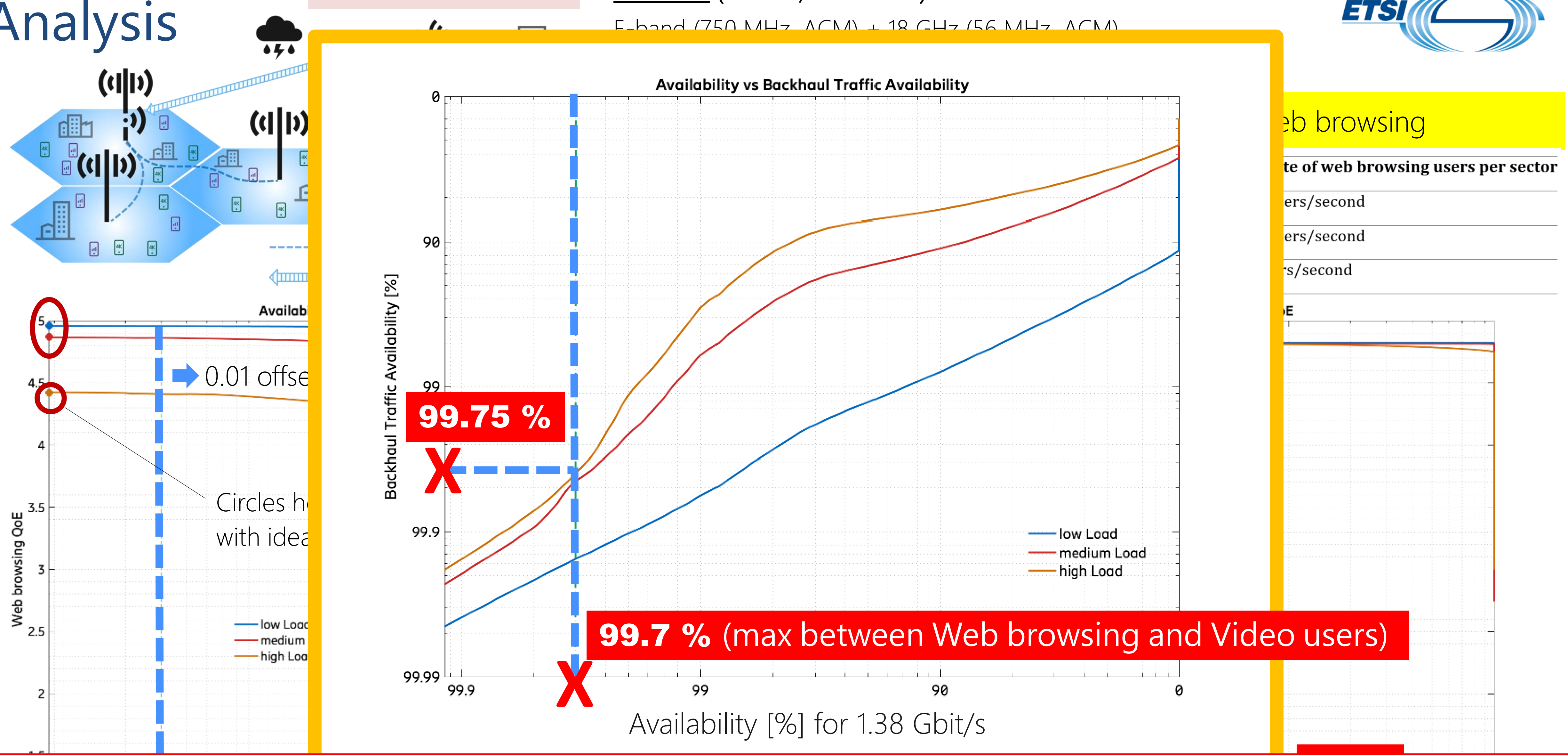
Analysis


SOURCE: Ericsson
Backhaul (35 mm/h rain rate)
Availability vs Backhaul Traffic Availability
Backhaul Traffic Availability [%]
99.75 %
99.7 % (max between Web browsing and Video users)
low Load
medium Load
high Load
Availability [%] for 1.38 Gbit/s
eb browsing
te of web browsing users per sector
ers/second
ers/second
s/second
Web browsing QoE
0.01 offse
Circles h
with idea
99.7 %
RAN at 70% utilization
Availability [%] for 1.38 Gbit/s
93 %
Availability [%] for 1.38 Gbit/s

Analysis

SOURCE: Ericsson

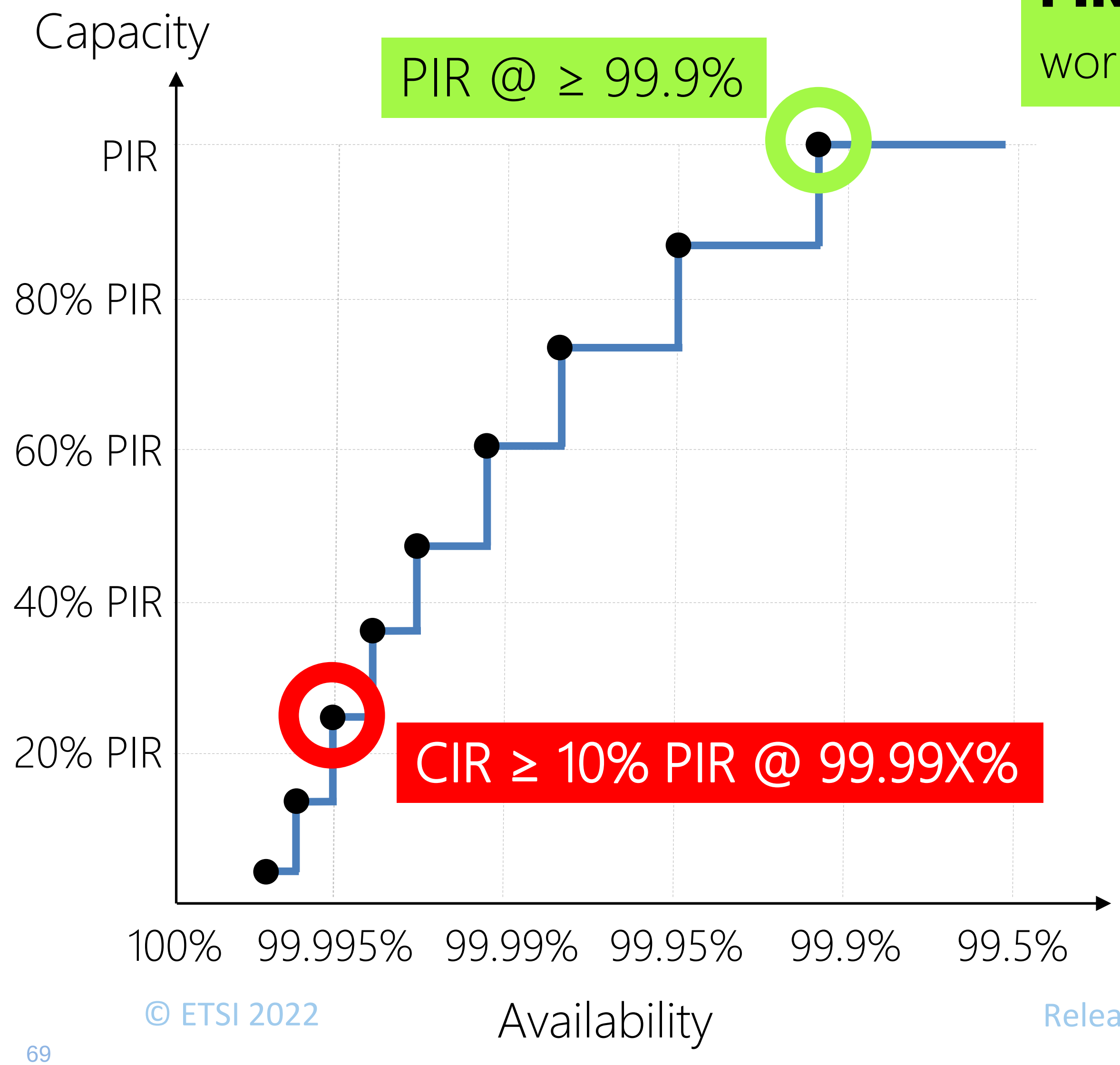
Backhaul (35 mm/h rain rate)



BTA can be as low as **99.75%**, and still the Video users and Web browsing users will have **near-ideal QoE**

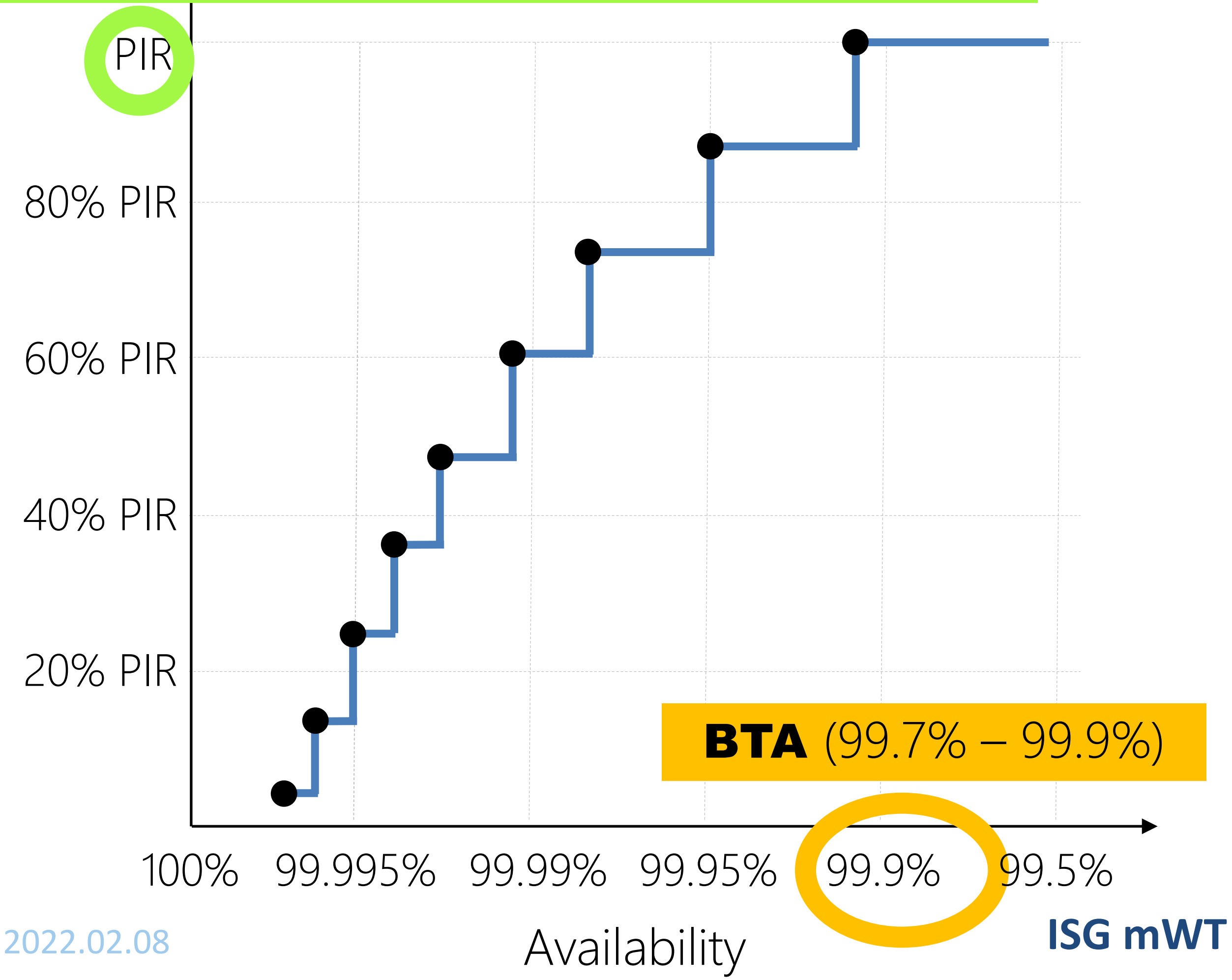
Towards a 3 Check Points Planning Method

Current 2 Check Points Planning



Proposed 3 Check Points Planning

PIR with fade margin (5-10 dB) for ensuring stable working conditions and with no availability requirements



Content

A New CIR Definition

CIR @ 99.99X% = **Traffic for network survivability** + **MNO-specific top priority services**

Traffic for network survivability = RAN C-plane + RAN S-plane + RAN M-plane

- RAN C-plane: ~0.5% of PIR for 4G/5G
- RAN S-plane: < 1 Mbit/s
- RAN M-plane: 3-5 Mbit/s for 4G/5G

MNO-specific top priority services:

- *voice traffic*: < 30 Mbit/s
- *GBR services*
- *SLA services*

CIR should **not** be simply estimated as a **percentage of PIR**

- baseline values landing in the range 1-2 % of PIR in case of PIR = 3 Gbit/s for 4G/5G backhaul
- extra traffic for GBR and ultra-Reliable services has no dependency on PIR

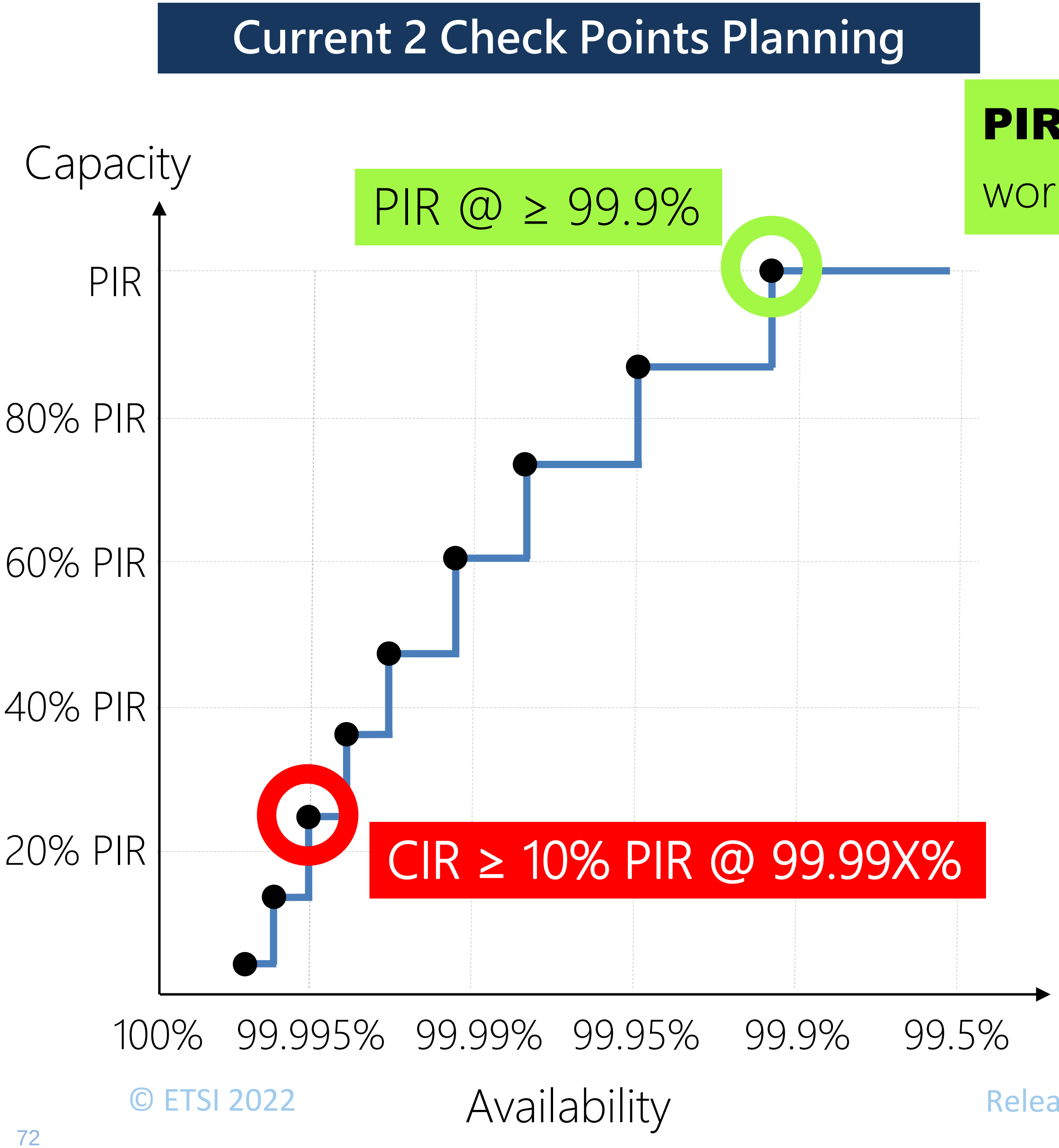
Lower bound

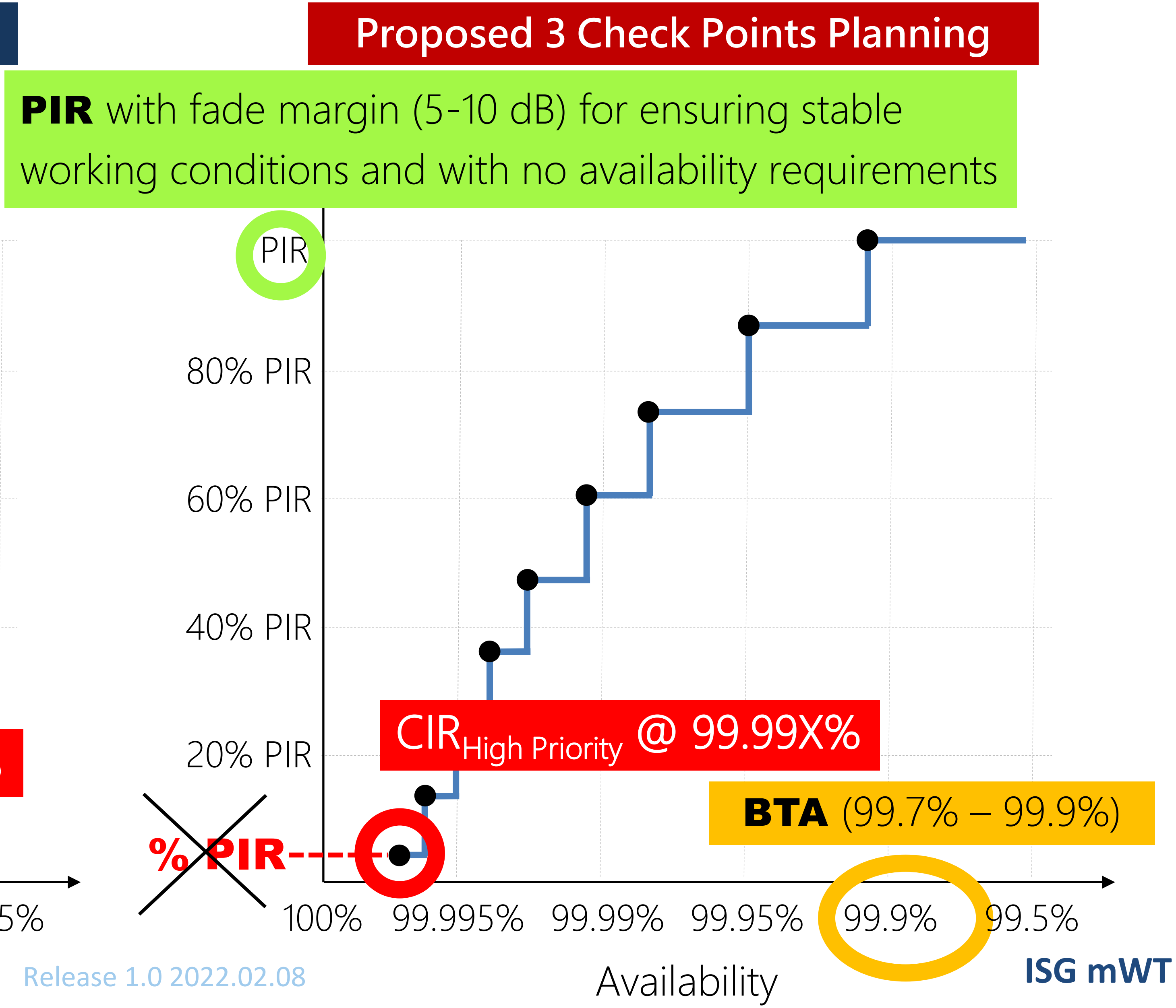
		RAN survivability (Mbps)			Top priority services (Mbps)			
	PIR (Gbps)	C-Plane	S-Plane	M-Plane	Voice	GBR	uR (SLA)	CIR (Mbps)
4G site	0,5	2,5	1	3	15	0	0	21,5
5G site	2,5	12,5	1	3	15	MNO specific		31,5 + MNO specific
4G + 5G site	3	15	1	6	15			37 + MNO specific

Upper bound

		RAN survivability (Mbps)			Top priority services (Mbps)			
	PIR (Gbps)	C-Plane	S-Plane	M-Plane	Voice	GBR	uR (SLA)	CIR (Mbps)
4G site	0,5	2,5	1	5	30	0	0	38,5
5G site	2,5	12,5	1	5	30	MNO specific		48,5 + MNO specific
4G + 5G site	3	15	1	10	30			56 + MNO specific

Towards a 3 Check Points Planning Method





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Planning Example 1 – E band (1 GHz, Single Pol) + 18 GHz (56 MHz, Dual Pol)

current planning
PIR @ ≥ 99.9%
CIR ~ 10% PIR @ ≥ 99.995%

(42 mm/h)

5 km

Capacity (Mbit/s)	Availability (%)
78	100,000%
89	100,000%
225	100,000%
340	99,999%
490	99,995%
725	99,988%
1311	99,977%
2864	99,958%
3676	99,951%
4417	99,937%
5193	99,907%

CIR ≈ 9.4% PIR

PIR

BTA = 99.970%
(with RAN peak-to-median ≈ 3)

high traffic load condition

Planning Example 1 – E band (1 GHz, Single Pol) + 18 GHz (56 MHz, Dual Pol)

current planning
PIR @ ≥ 99.9%
CIR ~ 10% PIR @ ≥ 99.995%

new planning – 1
BTA ≥ **99.9%**
CIR ~ 1.5% PIR @ ≥ 99.995%

(42 mm/h)

5 km → **x1.76** → **8,8 km**

Capacity (Mbit/s)	Availability (%)
78	100,000%
89	100,000%
225	100,000%
340	99,999%
490	99,995%
725	99,988%
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5193	99,907%

CIR ≈ 9.4% PIR

PIR

BTA = 99.970%
(with RAN peak-to-median ≈ 3)

Capacity (Mbit/s)	Availability (%)
78	99,999%
89	99,9[illegible]
225	99,997%
340	99,992%
490	99,967%
1311	99,924%
2088	99,909%
2864	99,860%
3676	99,835%
4417	99,783%
5193	99,657%

CIR ≈ 1.5% PIR

PIR

BTA = 99.9%
(with RAN peak-to-median ≈ 3)

Planning Example 1 – E band (1 GHz, Single Pol) + 18 GHz (56 MHz, Dual Pol)

current planning
PIR @ ≥ 99.9%
CIR ~ 10% PIR @ ≥ 99.995%

new planning – 1
BTA ≥ **99.9%**
CIR ~ 1.5% PIR @ ≥ 99.995%

new planning – 2
BTA ≥ **99.8%**
CIR ~ 1.5% PIR @ ≥ 99.995%

(42 mm/h)

5 km → **x1.76** → **8,8 km** → **x2.4** *(from 5 km)* → **12,1 km**

5 km

Capacity (Mbit/s)	Availability (%)
78	100,000%
89	100,000%
225	100,000%
340	99,999%
490	99,995%
725	99,988%
1311	99,977%
2864	99,958%
3676	99,951%
4417	99,937%
5193	99,907%

CIR ≈ 9.4% PIR

PIR

BTA = 99.970%
(with RAN peak-to-median ≈ 3)

8,8 km

Capacity (Mbit/s)	Availability (%)
78	99,999%
89	99,9
225	99,997%
340	99,992%
490	99,967%
1311	99,924%
2088	99,909%
2864	99,860%
3676	99,835%
4417	99,783%
5193	99,657%

CIR ≈ 1.5% PIR

PIR

BTA = 99.9%
(with RAN peak-to-median ≈ 3)

12,1 km

Capacity (Mbit/s)	Availability (%)
78	99,998%
89	99,9
225	99,991%
340	99,981%
448	99,953%
1265	99,853%
2088	99,789%
2864	99,719%
3676	99,664%
4417	99,541%
5193	99,203%

CIR ≈ 1.5% PIR

PIR

BTA = 99.801%
(with RAN peak-to-median ≈ 3)

Planning Example 1 – E band (1 GHz, Single Pol) + 18 GHz (56 MHz, Dual Pol)

current planning
PIR @ ≥ 99.9%
CIR ~ 10% PIR @ ≥ 99.995%

new planning – 1
BTA ≥ **99.9%**
CIR ~ 1.5% PIR @ ≥ 99.995%

new planning – 2
BTA ≥ **99.8%**
CIR ~ 1.5% PIR @ ≥ 99.995%

(42 mm/h)

5 km — **x1.76** → **8,8 km** — **x2.4** *(from 5 km)* → **12,1 km**

5 km

Capacity (Mbit/s)	Availability (%)
78	100,000%
89	100,000%
225	100,000%
340	99,999%
490	99,995%
725	99,988%
1311	99,977%
2864	99,958%
3676	99,951%
4417	99,937%
5193	99,907%

CIR ≈ 9.4% PIR

PIR

BTA = 99.970%
(with RAN peak-to-median ≈ 3)

8,8 km

Capacity (Mbit/s)	Availability (%)
78	99,999%
89	99,9[illegible]
225	99,997%
340	99,992%
490	99,967%
1311	99,924%
2088	99,909%
2864	99,860%
3676	99,835%
4417	99,783%
5193	99,657%

CIR ≈ 1.5% PIR

PIR

BTA = 99.9%
(with RAN peak-to-median ≈ 3)

12,1 km

Capacity (Mbit/s)	Availability (%)
78	99,998%
89	99,9[illegible]
225	99,991%
340	99,981%
448	[illegible]
1265	[illegible]
2088	[illegible]
2864	[illegible]
3676	[illegible]
4417	[illegible]
5193	99,203%

CIR ≈ 1.5% PIR

6.5% PIR (e.g., with SLA traffic) is still delivered with high availability (<u>only 100 minutes of outage in a year</u>)

BTA = 99.801%
(with RAN peak-to-median ≈ 3)

Planning Example 2 – E band (1 GHz, Single Pol)

current planning
PIR @ ≥ 99.9%
CIR ~ 10% PIR @ ≥ 99.995%

new planning
BTA ≥ 99.9%
CIR ~ 1.5% PIR @ ≥ **99.995%**

(42 mm/h)

2.6 km → x1.54 → 4 km

Modulation	Capacity (Mbit/s)	Availability (%)
BPSK @ 125 MHz	94	99,998%
BPSK @ 250 MHz	189	99,997%
BPSK @ 500 MHz	381	99,996%
BPSK @ 1000 MHz	775	99,995%
QPSK	1552	99,994%
16QAM	3140	99,989%
32QAM	3881	99,985%
64QAM	4657	99,978%
128QAM	5433	99,966%
256QAM	6209	99,957%

CIR ≈ 12% PIR

PIR

BTA = 99.990%
(with RAN peak-to-median ≈ 3)

Modulation	Capacity (Mbit/s)	Availability (%)
BPSK @ 125 MHz	94	99,995%
BPSK @ 250 MHz	189	99,991%
BPSK @ 500 MHz	381	99,989%
BPSK @ 1000 MHz	775	99,986%
QPSK	1552	
16QAM	3140	
32QAM	3881	
64QAM	4657	
128QAM	5433	
256QAM	6209	99,884%

CIR ≈ 1.5% PIR

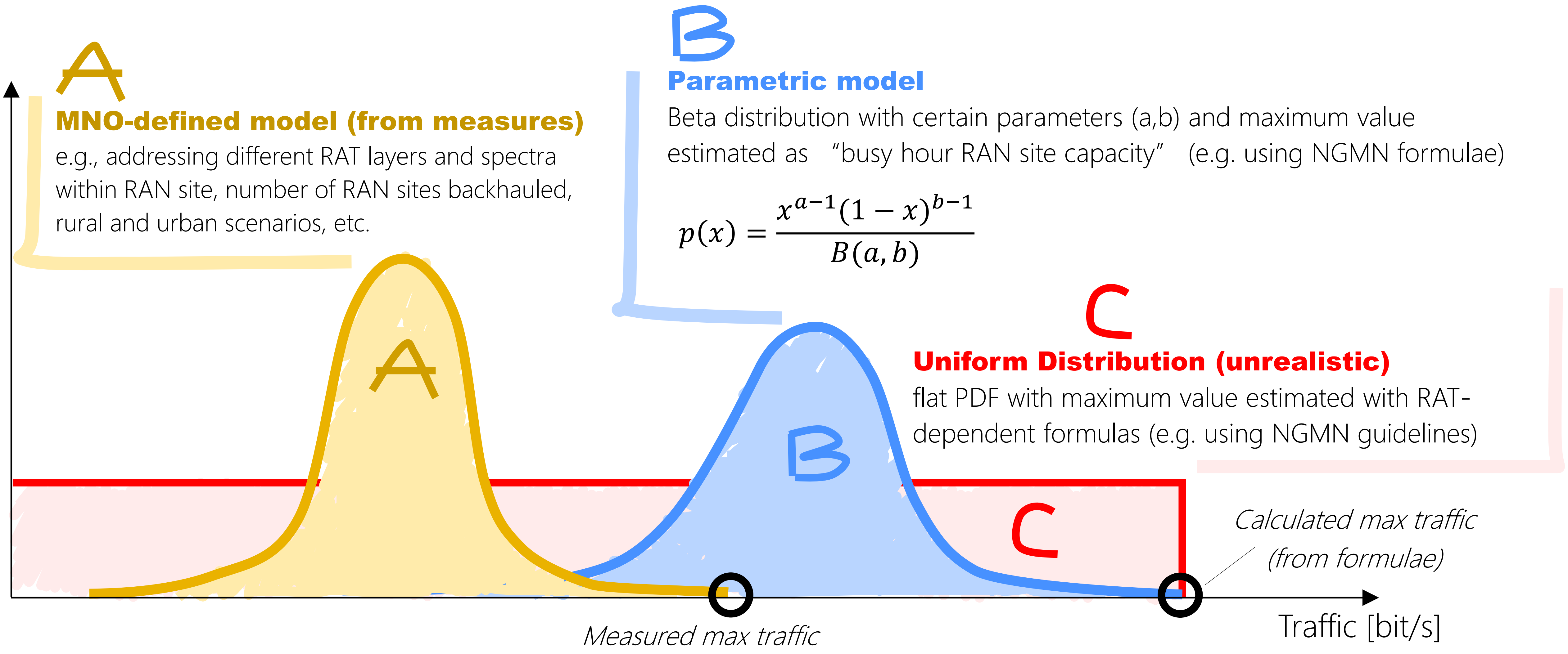
12% PIR (that could represent SLA traffic) is still delivered with high availability (<u>only 73 minutes of outage in a year</u>)

PIR

BTA = 99.972%
(with RAN peak-to-median ≈ 3)

Content

RAN traffic PDF curves represent the amount of traffic to be delivered to make all End Users **happy**



time granularity lower limit impacting user experience is in the "one second" range

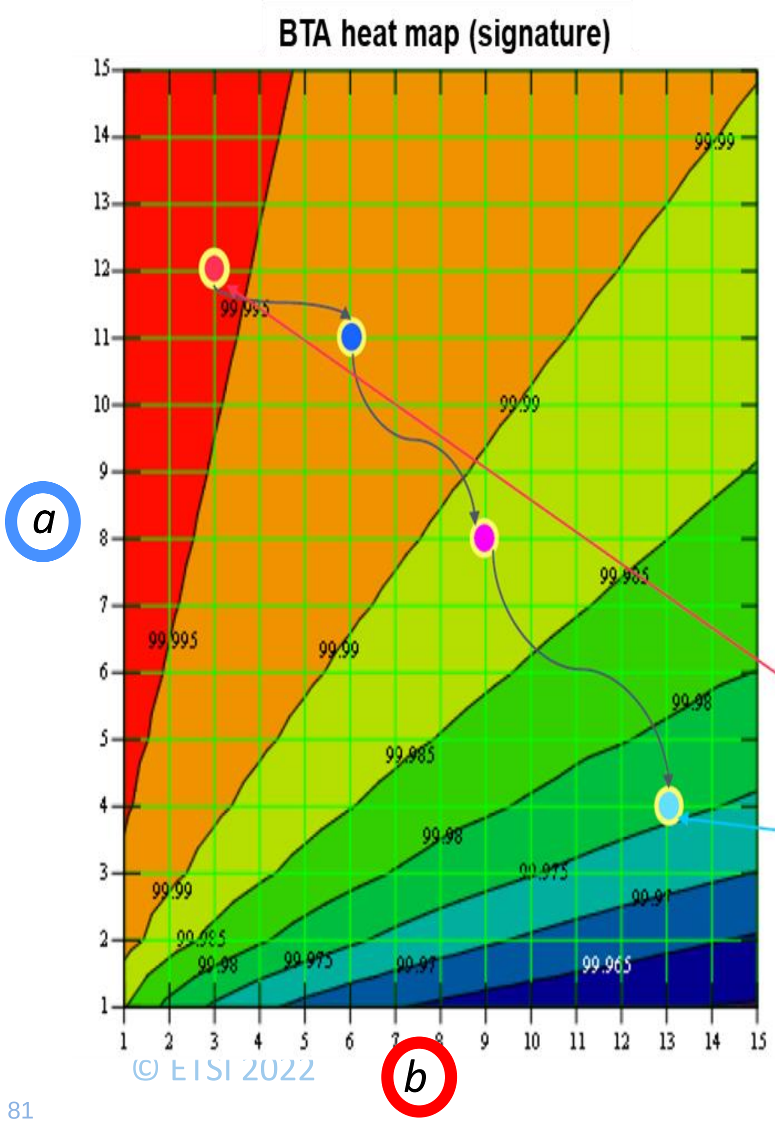
Network Planning

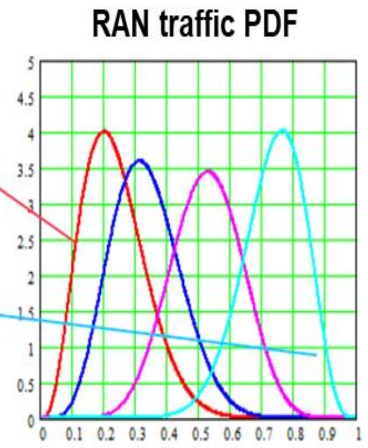
No changes on propagation-related **fading prediction models** (ITU-R P.530)

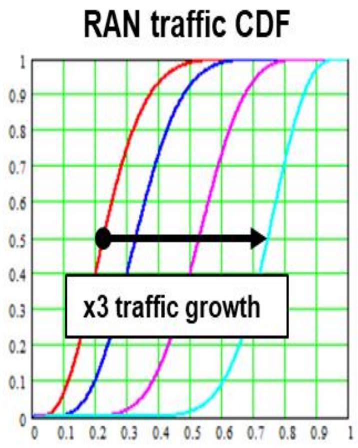
Planning tools will additionally evaluate **BTA** based on:

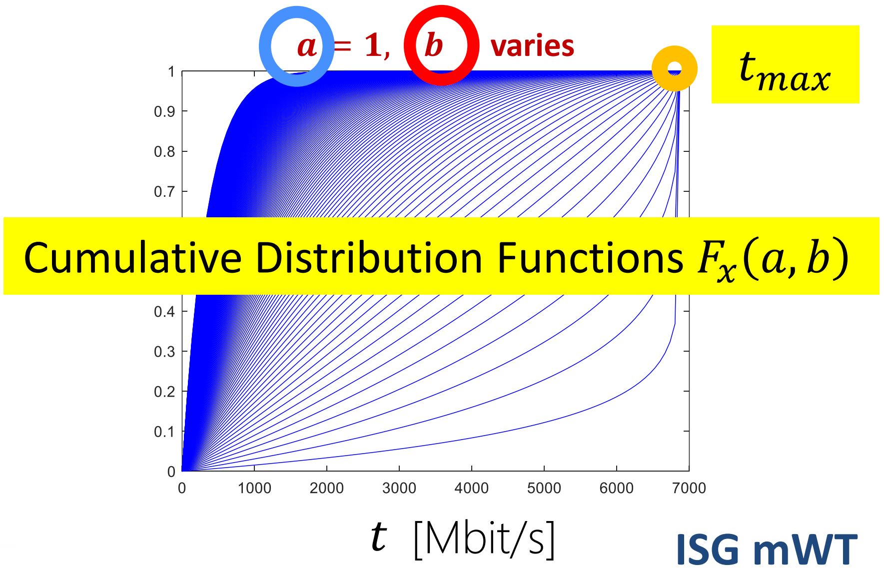
- a vector of **BH capacity** and **availability pairs** accounting for the ITU-R P.530 fading prediction models
- a **RAN traffic PDF** (based on measurements or parametric models)

$$F_x(a,b) = \int_0^x \left(\frac{t}{t_{max}}\right)^{a-1} \left(1-\left(\frac{t}{t_{max}}\right)\right)^{b-1} dt \Bigg/ \int_0^1 \left(\frac{t}{t_{max}}\right)^{a-1} \left(1-\left(\frac{t}{t_{max}}\right)\right)^{b-1} dt$$





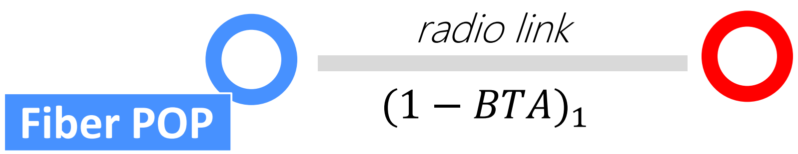




BTA Planning In Multi-hop Topologies

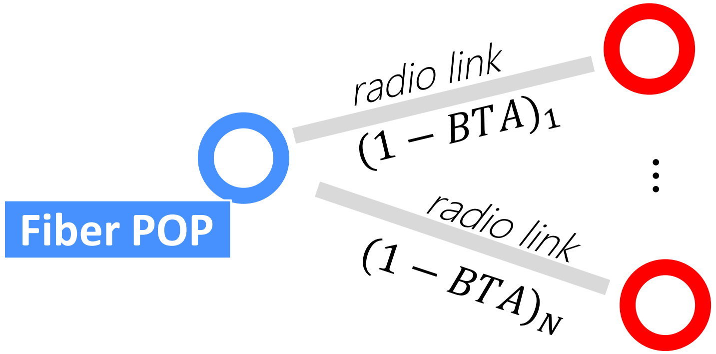
Set the overall MW Backhaul congestion probability target → $\mathbf{MW_{cong}}$

Single link to fiber POP



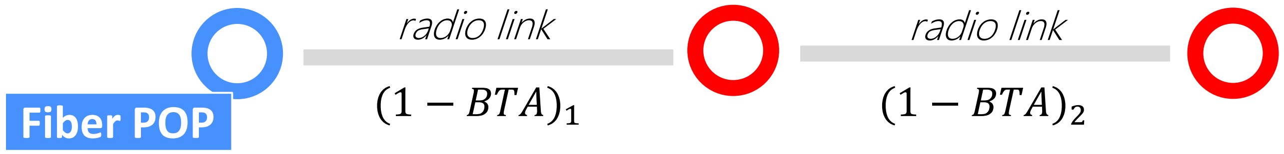
$$(1-BTA)_1 = MW_{cong}$$

Hub & Spoke on fiber POP



$$(1-BTA)_1 = \cdots = (1-BTA)_N = MW_{cong}$$

Daisy chain to fiber POP



$$(1-BTA)_1 + (1-BTA)_2 < MW_{cong}$$

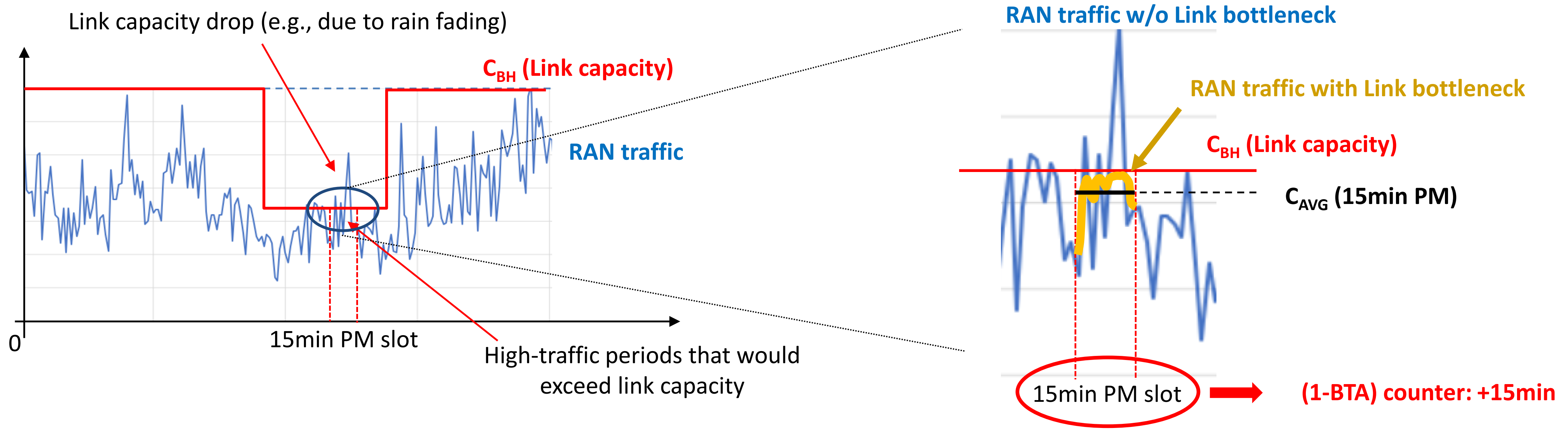
For example:

$$(1-BTA)_1 = \frac{1}{3}\, MW_{cong}$$

$$(1-BTA)_2 = \frac{2}{3}\, MW_{cong}$$

Measuring BTA In Live Networks

(1-BTA) can be estimated with **currently available PM** counters (with 5-15 minutes granularity) for assessing the **adequacy status** of the Backhaul radio link in operations

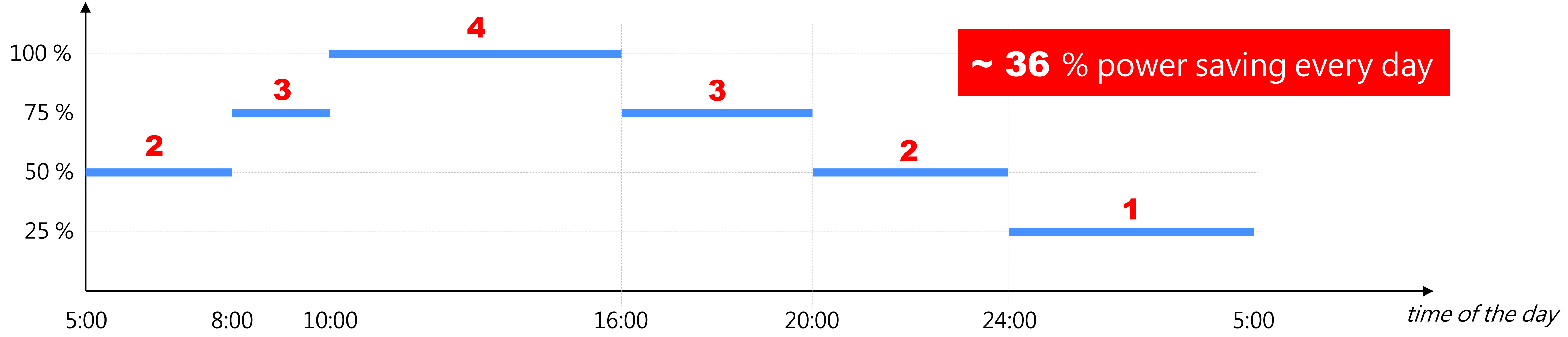


- **If $(C_{BH} – C_{AVG})/C_{BH}$ < threshold** (%) **=> Traffic congestion => (1-BTA) incremented** by 15 minutes
- Different PM time granularities (15min, 5min, etc.) lead to different thresholds (20%, 10%, 5%, etc.), that need to be tested and defined through network measurement campaigns

BTA To Monitor New Technologies Operation

Efficient power consumption is a new MW/mmWave technology that intentionally reduces the maximum available link capacity for several hours a day in order to optimize energy efficiency

% amount of traffic versus peak & number of activated carriers (exemplary long-haul link with a total of 4 carriers)



- BTA can be used to assess residual risk to create RAN traffic congestions during "predicted low traffic periods", therefore allowing the MNO to set proper rules for defining low traffic periods, considering prediction algorithms accuracy
- BTA can be used both in the planning phase and during network operation

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Conclusions

- Introduction of New KPIs for the evaluation of performance and availability of wireless Backhaul to **avoid over-engineering** of the hops, or equivalently, to extend hop lengths especially for E-Band and Band Aggregation

- Make **wireless Backhaul** as part of the **overall E2E network** moving from availability of a Backhaul capacity to the availability of traffic according to the RAN requirements
  - **Why** requiring **99.9% availability** for a **peak rate** that is demanded by the RAN with a **small** probability?
  - Weigh Backhaul outage probabilities with the probability distribution function of the RAN traffic => definition of **BTA** – Backhaul Traffic Availability
  - Define targets for BTA on the basis of E2E QoE of the RAN Users – simulations outcomes demonstrate that **BTA target** can be pushed up to **99.7%** - **99.9%** with negligible impact on End User Quality of Experience with respect to the ideal Backhaul scenario for any mix of services analyzed
  - **Definition of CIR** based on RAN sites survivability and very high value traffic

- Towards a new planning method based on **3 Check Points** (**CIR** for very high priority traffic, **PIR** with 5-10 dB fade margin, **BTA** @ 99.7% – 99.9%)

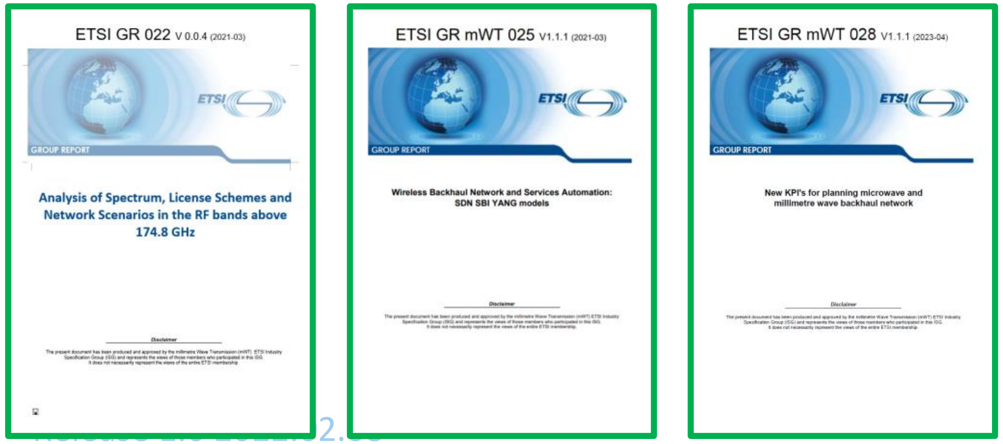
Future Work

- **Promotion** of the novel vision and paradigm with other Standardization Bodies and Local National Administrations

- Identification of further **technical contributions** from ETSI ISG mWT Members to improve the "New KPIs" ecosystem and to ease its adoption in next generation **planning** tool **releases**, with emphasis on the definition of application-specific traffic distribution benchmarks

- Promotion of **pilot projects** and **experiments** focused both on corroborating the value of the novel planning approach and on assessing its impacts on real network scenarios

- **Investigation** of the "New KPIs" paradigm in more complex wireless Backhaul **network** scenarios



Thank You

The mWT ISG is open to all ETSI members and non-members

For full details of the mWT ISG activity follow us at
https://portal.etsi.org//tb.aspx?tbid=833&SubTB=833