Lecture on determining the required bandwidth for a particular facility (settlement, school, hospital, etc.)

General principles of traffic transmission in packet networks

Telecommunication networks are being developed to provide necessary conditions for the practical application of different aspects of human life. One of such conditions is the multiservice traffic with the set of quality of service (QoS) indicators

To calculate the required bandwidth of such external channels it is necessary to identify the number of simultaneous sessions that could be served by the channel without loosing Quality of Experience (QoE) level
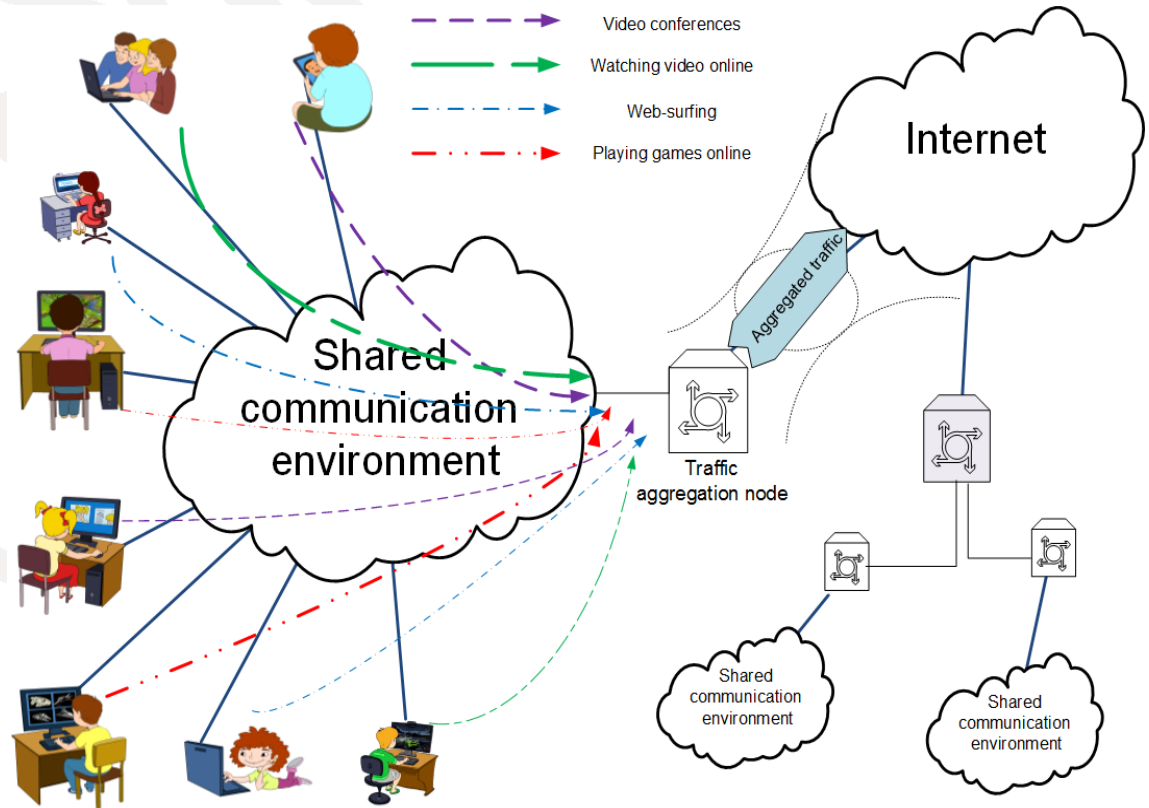
Traffic profile

To determine the necessary external channel capacity for a specific network, connectivity traffic profile need to be defined

The number of traffic profile is based on the number of quality profiles and the number of intensity profiles. The total number of traffic profiles (N_P) can be calculated by following formula:

$$N_P = N_{QL} \times N_{IL}$$

where N_{QL} – number of quality levels;
N_{IL} – number of intensity levels

List of services with their quality and intensity parameters

Service	Quality Parameters			Intensity Parameters		
Service 1	...	...	...	...	...	...
Service 2	...	...	...	...	...	...
....	...	...	...	...	...	...
....	...	...	...	...	...	...
Service Ns	...	...	...	...	...	...

User Device Group Nud
User Device Group ....
User Device Group 2
User Device Group 1

Services	Quality Parameters			Intensity Parameters		
Service 1	...	...	...	...	...	...
Service 2	...	...	...	...	...	...
....	...	...	...	...	...	...
....	...	...	...	...	...	...
Service Ns	...	...	...	...	...	...

Traffic Profile
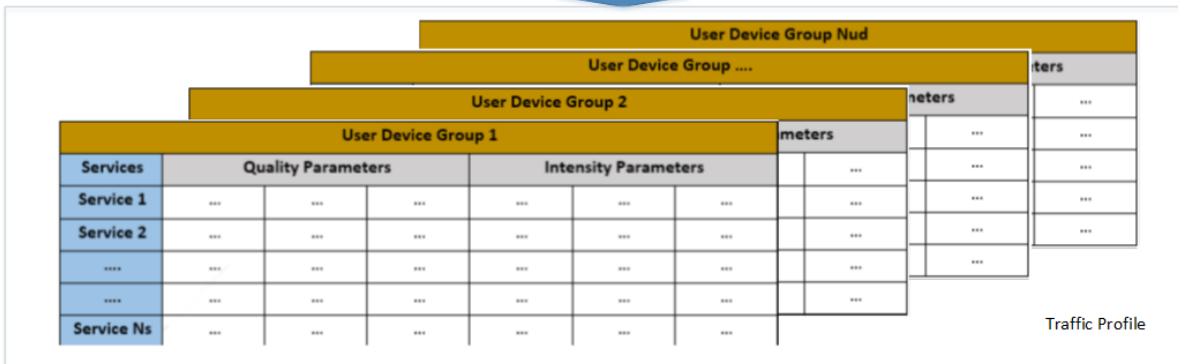
		Services				
		Service 1	Service 2	....	....	Service Ns
User Devices Groups (UDGs)	UDG 1	Low	Not used	High	Med	Low
	UDG 2	Not used	High	Low	Low	High
	....	...	...	...	...	...
	....	...	...	...	...	...
	UDG Nud	Low	Not used	High	Med	Low

Information about services usage profiles for each user device groups

Quality and Intensity Profiles

- **Quality Profile** - a set of parameters, such as data rate (per session), latency, and probability of deterioration, that describe the degree of quality of service that a user receives during use. The quality profile can be low, medium or high.

  The parameters of Quality Profiles are:
  Data transmission rate(per session) in Mbit/s;
  Maximum latency in ms;
  QoE (Quality of Experience) degradation probability in %.

- **Intensity Profile** is a set of parameters such as the number of requests in hours and the amount of data that is transferred within a single session, which uses the rate of use of the service (the number of concurrent sessions).

  The parameters of Intensity Profiles are:
  Requests for service, requests per hour;
  Volume of data per session, MB;
  Number of simultaneous sessions.

Examples of Traffic Connectivity Profiles

#	Profile Name	Profile Description	Quality Level	Intensity Level
1	Basic-	Users in hard-to-reach areas (including rural areas) in the countries where the internal backbone is not developed yet and/or the external connectivity to the international communication channels is poor, with low intensity of service using	Low	Low
2	Basic	Users in hard-to-reach areas (including rural areas) in the countries where the internal backbone is not developed yet and/or the external connectivity to the international communication channels is poor, with medium intensity of service using	Low	Medium
3	Basic+	Users in hard-to-reach areas (including rural areas) in the countries where the internal backbone is not developed yet and/or the external connectivity to the international communication channels is poor, with high intensity of service using	Low	High
4	Intermediate-	Users in developing countries with average broadband coverage and more than one external international communication channel, with low intensity of service using	Medium	Low
5	Intermediate	Users in developing countries with average broadband coverage and more than one external international communication channel, with medium intensity of service using	Medium	Medium
6	Intermediate+	Users in developing countries with average broadband coverage and more, than one external international communication channel, with high intensity of service using	Medium	High
7	Advanced-	Users in developed countries with good broadband coverage and international communication channels, with low intensity of service using	High	Low
8	Advanced	Users in developed countries with good broadband coverage and international communication channels, with medium intensity of service using	High	Medium
9	Advanced+	Users in developed countries with good broadband coverage and international communication channels, with high intensity of service using	High	High

EXAMPLE OF SERVICES CLASSIFICATION

Transmission mode	Classified Typical service	Text/Graphics-based Learning Management System	Multimedia Learning Management System (incl. video)	Remote CCTV cameras	Podcasts	Public Video conference service (Zoom, Microsoft Teams, Skype, etc.)	Online banking	Cloud-based slideshow	LIMS	Big Data	Remote distributed cloud calculation	Smart house hub	Drone signal	On-line TV	IP telephony	Mining (IIT)
Real-Time	Conversational voice					*									*	
	High quality streaming audio				*											
	Video conference					*										
	Broadcast													*		
	Video streaming		*	*									*	*		
Non-real Time	Web-browsing	*	*													
	Data transfer/ retrieval									*	*					*
	Transaction services						*									*
	Command/ control											*	*			
	Services for group work	*	*			*		*								
	Still image							*								
	Specialized software								*							

TYPES OF SERVIES

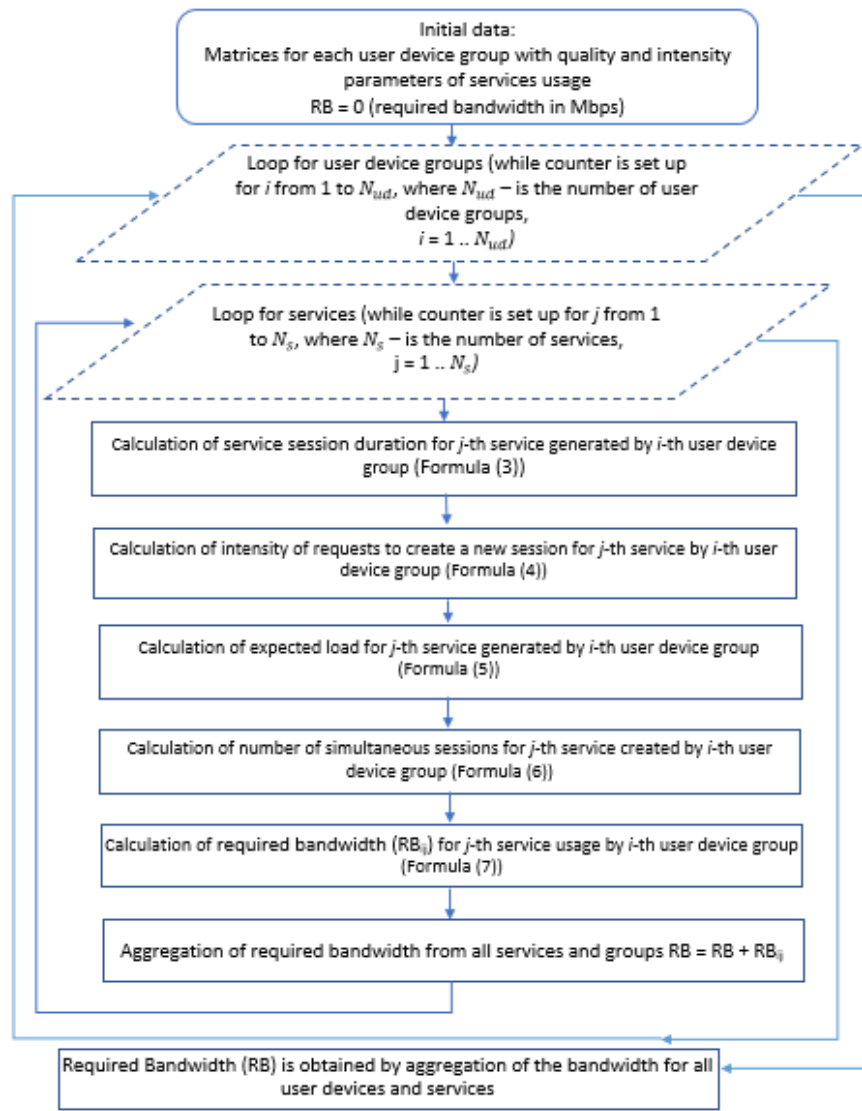| Scope	Object type	General Connectivity Applications Profile						
		Office	Home	Science	Healthcare	Education	Rural	Industrial
Households	Rural		+		+	+	+	
	Urban	+	+	+	+	+		+
Education & Science	School	+				+		
	University	+		+		+		
	R&D office	+		+				
Medicine	Hospital	+			+			
	Medical Center	+			+			
Business	Store	+						
	Supermarket	+						
	Bakery	+						
	IT office	+		+				
	Bank	+						
	Farm	+					+	
	Restaurant	+						
	Hotel	+	+					
	Other	+						
Industry	Warehouse	+					+	+
	Factory							+
	Other							+
Administrative	Post Office	+					+	
	Administration	+					+	
	Other	+						
Culture & sport	Museum	+				+		
	Theatre	+						
	Stadium	+						
	City park	+						
	Other	+						
Transport	Vehicle repair	+						
	Bus station	+						
	Gas Station	+						
	Other	+						

Methodology

➢ The required bandwidth for the external channel is defined as the aggregate network subscribers' traffic for all services. This methodology is applicable to the different kind of objects, including social (educational, healthcare etc.) institutions or commercial subscribers in some locality.

#	Description	Symbol	Unit
1	Information volume by one standard session for a service	L	MB
2	Enough bitrate for service usage with a given level of quality	V	Mbps
3	Service usage intensity by one user (subscriber) – the number of requests	I	request per hour
4	QoE degradation probability	P	%

➢ The required bandwidth is determined from the calculation of the aggregate network traffic from all the subscribers. Hence, in accordance with the intensity of resource usage for each type of user, profiles of the intensity of services usage have been developed: LOW, MEDIUM and HIGH, respectively.

Algorithm for required bandwidth calculation

Initial data:
Matrices for each user device group with quality and intensity parameters of services usage
RB = 0 (required bandwidth in Mbps)

Loop for user device groups (while counter is set up for i from 1 to N_{ud}, where N_{ud} – is the number of user device groups, $i = 1 .. N_{ud}$)

Loop for services (while counter is set up for j from 1 to N_s, where N_s – is the number of services, $j = 1 .. N_s$)

Calculation of service session duration for j-th service generated by i-th user device group (Formula (3))

Calculation of intensity of requests to create a new session for j-th service by i-th user device group (Formula (4))

Calculation of expected load for j-th service generated by i-th user device group (Formula (5))

Calculation of number of simultaneous sessions for j-th service created by i-th user device group (Formula (6))

Calculation of required bandwidth (RB_{ij}) for j-th service usage by i-th user device group (Formula (7))

Aggregation of required bandwidth from all services and groups RB = RB + RB_{ij}

Required Bandwidth (RB) is obtained by aggregation of the bandwidth for all user devices and services

The required bandwidth calculation algorithm is comprised of five steps.

1) Calculation of session duration (in seconds) for each service;

2) Calculation of overall intensity of requests to create new session for each service;

3) Calculation of expected load (in Erlangs) for each service;

4) Calculation of number of simultaneous sessions for each service.

5) Calculation of required bandwidth for each service.

The resulting value of required bandwidth is calculated as a sum of required bandwidth for all services.

Description	Formula	Units	Initial data
Calculation of service session duration (T_{ij}) for *j*-th service generated by *i*-th user device group	$$T_{ij} = \left(8.38 \times L_{ij}\right)/V_j \ (3)$$	seconds	$i = 1,2,..,N_{ud}$ N_{ud} – Number of User device groups $j = 1,2,..,Ns$ Ns – Number of services within connectivity traffic profile L_{ij} – Volume of data per session for *j*-th service (according to level of Intensity that was chosen for *i*-th user device group), MB V_j – Data transfer rate (for one session) for *j*-th service (according to chosen level of Quality), Mbit/s 8.38 – relation between number of bits in 1MB to 1 million bits – $1024 \times 1024 \times 8/1000000$ (1024 KB in 1MB, 1024 bytes in 1KB, 8 bits in 1 byte)

Description	Formula	Units	Initial data
Calculation of intensity of requests (λ_{ij}) to create a new session for j-th service by i-th user device group	$$\lambda_{ij} = C_i \times I_{ij} \quad (4)$$	requests/ hour	$$i = 1 .. N_{ud}$$ N_{ud} – Number of User device groups $$j = 1, 2, .., Ns$$ Ns Number of services in the connectivity traffic profile C_i – Number of user devices within i-th group I_{ij} – Intensity of usage for j-th service by i-th user device group, requests/hour

Algorithm for required bandwidth calculation

Description	Formula	Units	Initial data
Calculation of expected load (Y_{ij}) for j-th service generated by i-th user device group	$Y_{ij} = \lambda_{ij} \times (T_{ij}/3600)$ (5)	Erlangs	$i = 1 .. N_{ud}$ N_{ud} – Number of User device groups $j = 1, 2, .., Ns$ Ns – Number of services in the connectivity traffic profile T_{ij} – Service session duration for j-th service generated by i-th user device group (calculated by Formula (3)), seconds λ_{ij} – Intensity of requests to create a new session for j-th service by i-th user device group (calculated by Formula (4)), requests / hour 3600 – number seconds in an hour

Description	Formula	Units	Initial data
Calculation of number of simultaneous sessions (C_{ij}) for j-th service created by i-th user device group	$P_{qd} = \left((Y_{ij})^{C_{ij}}/(C_{ij})!\right)/\sum_{f=0}^{C_{ij}}\left((Y_{ij})^{f}/f)!\right)$ (6)	sessions	$i = 1..N_{ud}$ N_{ud} – Number of User device groups $j = 1, 2,.., Ns$ Ns – Number of services in the connectivity traffic profile Y_{ij} – Expected for j-th service generated by i-th user device group (calculated by Formula (5)), Erlangs P_{qd} – Quality of Experience (QoE) degradation probability, %

Algorithm for required bandwidth calculation

Description	Formula	Units	Initial data
Calculation of required bandwidth (RB$_{ij}$) for *j*-th service usage by *i*-th user device group	$$RB_{ij} = C_{ij} \times V_j \quad (7)$$	Mbps	$i = 1..N_{ud}$ N_{ud} – Number of User device groups $j = 1, 2, .., Ns$ Ns – Number of services in the connectivity traffic profile C_{ij} – number of simultaneous sessions for *j*-th service created by *i*-th user device group (calculated by Formula (6)) V_j is data transfer rate (for one session) for *j*-th service (according to chosen level of Quality), Mbps;

The following assumptions and principles are used to determine the Maximum Latency and Data Transmission Rate values:

1. Values for the Low level are defined as the maximum allowable values of the service characteristics, defined in the relevant regulatory documents (standards or recommendations), national standards, scientific and analytical studies. In the case where the group includes services that have different values, the higher value is selected

2. For the Medium level, depending on the type of characteristic, the values are increased or decreased by 50% (for example, for the Latency, the values are decreased by 50%, and for the Data Transfer Rate, the values are increased by 50%) relative to the values determined for the Low level.

3. For the High level, depending on the type of characteristic, the values are increased or decreased by 20% relative to the values determined for the Medium level.

4. There are some exceptions. When determining the latency for services that belong to Class 5. For this class, the latency value is not standardized. In this case, the value was defined as 50% more than the maximum value defined for Class 4, which is 1500ms. Likewise, when determining the Data transfer rate for services in the Streaming video group, including interactive online TV, live-stream trainings, individualized live video instructions etc.

Example of Traffic analysis results for educational institution

Considering the results of the traffic analysis, it is possible to estimate the intensity of the use of different services (the number of requests per hour per user), as well as the amount of data transferred during the session

#	Name of Service	Low		Medium		High	
		Intensity of Using (for one user), requests / hour	Volume of Data (per session), MB	Intensity of Using (for one user), requests / hour	Volume of Data (per session), MB	Intensity of Using (for one user), requests / hour	Volume of Data (per session), MB
1	Streaming video, including interactive online TV, live-stream trainings, individualized live video instructions etc.	0.21	137.5	0.42	275	0.63	412.5
2	Services for group & individual communication, including webinars, conferences, meetings, tutoring, etc.	0.002	67.5	0.004	135	0.006	202.5
3	Online virtual simulators, educational online games, etc.	0.004	50	0.008	100	0.012	150
4	Services for group work (virtual boards, online graphics, etc.)	0.0025	25	0.005	50	0.0075	75
5	Other Real Time Traffic Services	0.0025	50	0.005	100	0.0075	150
6	Recorded educational clips, video instructions, trainings, Individualized recorded video, multimedia courses etc.	0.00125	125	0.0025	250	0.00375	375
7	Learning management systems, including libraries, repositories, databases, educational web-services, services for storing information etc.	0.04	2.5	0.08	5	0.12	7.5
8	Web-surfing, Search engines, bookmarking services, etc. E-mail, FTP and other classic services	0.17	2.5	0.34	5	0.51	7.5
9	Discussion boards, Social media & networks, forums etc.	0.0875	0.75	0.175	1.5	0.2625	2.25
10	Calendars and organizers, including lessons planning. Government e-portal access. Reporting Services etc.	0.1	0.75	0.2	1.5	0.3	2.25
11	Other Non-Real Time Traffic Services	0.1	0.75	0.2	1.5	0.3	2.25

SOFTWARE TOOLS FOR CALCULATING THE REQUIRED BANDWIDTH FOR AN EXTERNAL CHANNEL OF SPECIFIC OBJECT

Based on the methodology described above, a software tool for creating communication traffic profiles and estimating the required bandwidth for a specific object https://bcalc.connectivity.tools was developed

THANKS FOR ATTENTION