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The Application of a Socio-Economic Indicator for Calculating the Bandwidth of a Backbone in a WAN

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ABSTRACT

In a regional network, the graph branches that describe it are not loaded equally with data traffic. A branch that is loaded with traffic will depend on the number of users in both nodes of the graph, the number of paths that pass through that branch which are defined by the algorithm for finding the shortest path, the position of the branch in the network, as well as the position of WAN in other neighbors' networks. The traffic on the branches that connect the nodes of a network is constantly changing. It is important to know the maximum load of a branch in order to adapt to the demand so that there are no communication barriers. The calculation of data traffic in these branches is possible to be calculated and to know the maximum traffic limit in the respective branches. The branches that are busiest with data traffic represent the backbone of the network. The calculation of the bandwidth of the branch is affected not only by the number of users but also by their structure. In this paper, bandwidth calculation on a main branch in a graph is done through a case study using SEI.

KEYWORDS

Bandwidth, Network Backbone, Socio-Economic Indicator, Traffic Matrix, Wide Area Network

1. INTRODUCTION

For computer networks where the number of users is small there is no need for planning and calculation because usually such networks meet the requirements for which they are built. It does not happen that the branches of such computer networks are 100% loaded. If the number of users of a regional computer network is large, planning should be done in accordance with the requirements for which the computer network is established. In this case, some calculations need to be made before such a network can be built. Since each network is specific, there is no one-size-fits-all model for planning (*Al-Wakeel, 2009*). This requires help from some scientific disciplines such as graph theory, neighbor matrix, algorithms for finding the shortest path, statistical data on population structure, data on the technical-technological level of computer network equipment, etc. In a computer network the branches which connect the graph nodes representing the network are not equally loaded with traffic. Some branches are loaded with more traffic and some with less data traffic and this is constantly changing. This paper identifies several graphical branches of a WAN that represent a backbone of the Network. This paper attempts to identify such branches in a regional network in the region. In order to have a forecast for the maximum data traffic capacities in these main branches, the bandwidth of these branches is calculated. These maximum limits should be known despite the fact that the capacity for data transfer in these branches rarely reaches the maximum level. The structure of the population

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such as: workers in the public sector, workers in enterprises, unemployed, students, pupils, others do not use the same and it is possible to measure This provides even more accurate possibilities for calculating the maximum limits of bandwidth of these key backbone graph using the Socio-Economic Indicator (SEI). The contribution of the paper is that for the most accurate bandwith calculation of a branch at a certain region in WAN, a parameter is used and it is SEI (Socio Economic Indicator) with data from the field where that WAN network is located.

2. CALCULATION AND PLANNING OF BANDWIDTH ON THE BACKBONE OF A WIDE AREA NETWORK A CASE STUDY

A graph describes the regional WAN network through nodes and branches. Graph nodes represent cities and branches the connections between them. Some branches in the graph are overloaded. This is because through these branches data is transferred not only of those nodes (cities) that connect them but here can also pass traffic which is dictated through the algorithm for finding the shortest route. The application of the methodology for planning WAN networks enables the calculation of Erlang and then the availability of these branches, which create the backbone of a regional network. In accordance with the calculations in these branches, which form the main pillar of the network, technology will be deployed, which justifies the demand with the same communication capacity and cost reasonableness. This eliminates communication expectations and increases the stability of the regional network. To calculate Erlang and Accessibility several actions will be included: the traffic matrix for each city, the number of households, the number of network users, the total traffic for each city, the communication matrix between all cities and the shortest route between the vertices of graphite. In this case, it is attempted to calculate through these parameters some of the branches that are busiest with traffic connecting several nodes (cities) of a region. These branches can be said to represent the backbones that connect several cities to a regional computer network.

3. THE MOST IMPORTANT STAGES TO GET TO CALCULATION OF BANDWIDTH IN BACKBONE OF A WAN

The most important stages to achieve the calculation of bandwidth in the branches of a graph are: creating the graph and measuring the distances between nodes, calculating the SEI, calculating the traffic for each city, calculating the intercity traffic (traffic matrix), implementation of the algorithm for finding the shortest path, calculation of Erlang in the branches that connect cities, calculation of bandwidth in the main branches (*Ahmedi, 2014)*.

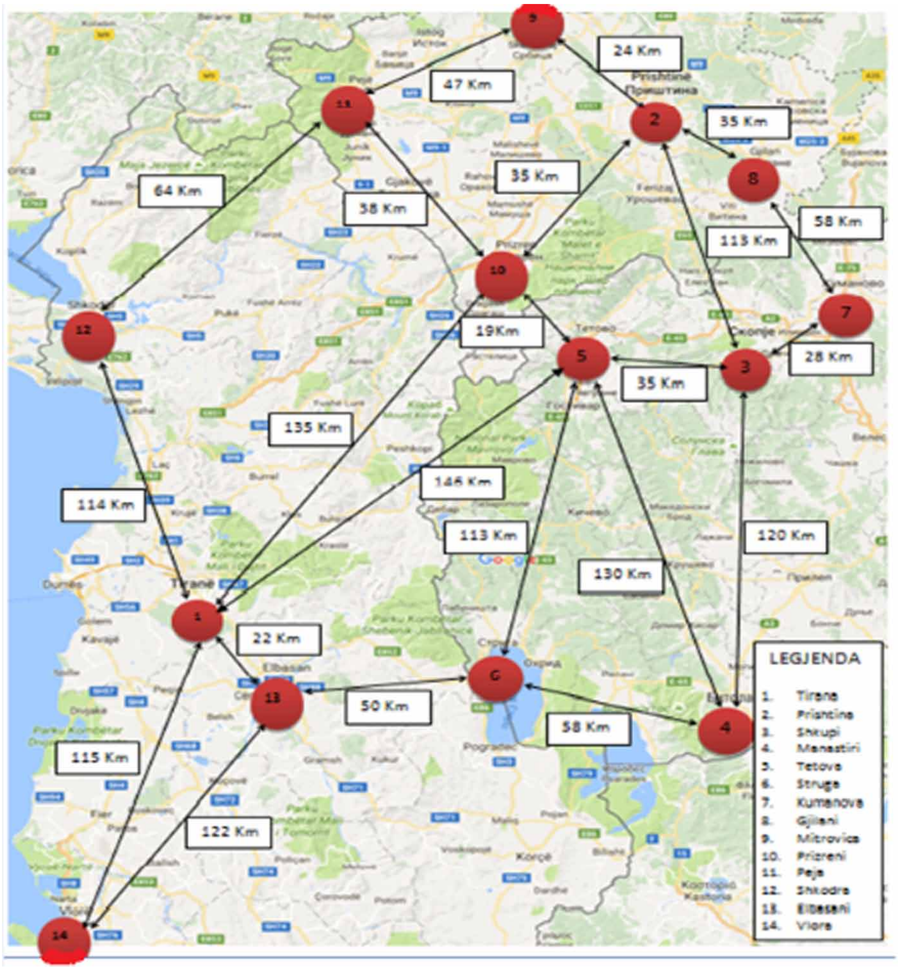
3.1 Creating the Graph And Measuring The Distances Between Nodes

The first step in planning a WAN is to create a graph that will out line the network. It consists of nodes which represent cities and branches which represent the connections between these nodes respectively cities. This is done to proceed further with the next steps for each node and each branch of the graph. There are some parameters that are treated in the following such as: number of families and structure, distance between nodes, position of the branch in the graph, etc.

3.2 SEI Calculation

The use of computer networks is not at the same level by the demographic structure of a city. It is quantified by a composite socioeconomic indicator (SEI), as a linear sum of products of weights w_i, and several measures of labor status and education, a_i ($0 \leq a_i \leq 1$ (Table 1). The weights w_i are defined on the basis of statistical reports *(Ahmedi, 2014*), *(De Montis, 2007*):

Figure 1. Creating the WAN network graph and the distance between nodes



$$SEI = \sum_{i=1}^{k} w_i a_i \qquad (1)$$

where :

a_1 – percentage of public employees in that city;
a_2 – percentage of employees in enterprises in that city;
a_3 – percentage of pupils in that city;
a_4 – percentage of students in that city;
a_5 – percent of unemployed in that city;
a_6 – percent of the other inhabitants.

$$a_1 = \frac{I_1}{P}, \quad 0_2 = \frac{I_2}{P}, \quad a_3 = \frac{I_3}{P}, \; a_4 = \frac{I_4}{P}, \quad a_5 = \frac{I_5}{P}, \; a_6 = \frac{I_6}{P} \qquad (2)$$

Table 1. Traffic SEI (Socio Economic Indicator)

	Cityes	Households	Populationa	w1	w2	w3	w4	w5	w6	N	employees	I1		I2		I3			I4		I5		I6		SEI
				level of the republic								no. public sector (40%)	$a_1=I_1/N$	no.business sector (60%)	$a_2=I_2/N$	elementary students	High School students	$a_3=I_3/N$	no. students	$a_4=I_4/N$	no. Unemployed	$a_5=I_5/N$	no. Other	$a_6=I_6/N$	
1	Struga	18107.43	63376	0.720	0.960	0.964	0.964	0.25	0.25	63376	47811	19124.4	0.302	28686.6	0.453	6006	3229	0.146	0	0	3034	0.048	3296	0.052	0.546
2	Manastiri	27252.86	95385	0.720	0.960	0.964	0.964	0.25	0.25	95385	66955	26782	0.281	40173	0.421	7421	4604	0.126	2973	0.031	6838	0.072	6594	0.069	0.541
3	Tetova	24737.14	86580	0.720	0.960	0.964	0.964	0.25	0.25	86580	41528	16611.2	0.192	24916.8	0.288	10114	9795	0.230	6670	0.077	9761	0.113	8712	0.101	0.591
4	Shkupi	144836.00	506926	0.720	0.960	0.964	0.964	0.25	0.25	506926	347236	138894.4	0.274	208341.6	0.411	53586	27692	0.160	32911	0.065	15874	0.031	29627	0.058	0.585
5	Kumanova	30138.29	105484	0.720	0.960	0.964	0.964	0.25	0.25	105484	68606	27442.4	0.260	41163.6	0.390	11303	6514	0.169	1732	0.016	6472	0.061	10857	0.103	0.548
6	Prishtina	136374.86	477312	0.720	0.960	0.964	0.964	0.25	0.25	209554	70517	28206.8	0.135	42310.2	0.202	30517	11083	0.199	55731	0.266	18706	0.089	23000	0.110	0.667
7	Prizreni	50794.57	177781	0.720	0.960	0.964	0.964	0.25	0.25	186860	130787	52314.8	0.280	78472.2	0.420	24059	7691	0.170	4253	0.023	10200	0.055	9870	0.053	0.565
8	Gjilani	25765.14	90178	0.720	0.960	0.964	0.964	0.25	0.25	88307	48883	19553.2	0.221	29329.8	0.332	12917	5198	0.205	2805	0.032	9650	0.109	8854	0.100	0.560
9	Peja	26985.71	94450	0.720	0.960	0.964	0.964	0.25	0.25	99154	53368	21347.2	0.215	32020.8	0.323	13639	4935	0.187	5432	0.055	11230	0.113	10550	0.106	0.560
10	Mitrovica	66523.71	232833	0.720	0.960	0.964	0.964	0.25	0.25	72597	40048	16019.2	0.221	24028.8	0.331	11679	4240	0.219	1923	0.026	7821	0.108	6886	0.095	0.566
11	Tirana	254165.14	889578	0.720	0.960	0.964	0.964	0.25	0.25	997380	725036	290014.4	0.291	435021.6	0.436	57454	39890	0.098	94500	0.095	45000	0.045	35500	0.036	0.572
12	Vlora	36084.00	126294	0.720	0.960	0.964	0.964	0.25	0.25	374168	291304	116521.6	0.311	174782.4	0.467	17598	10366	0.075	15000	0.040	23000	0.061	16900	0.045	0.530
13	Elbasani	79075.71	276765	0.720	0.960	0.964	0.964	0.25	0.25	423757	328527	131410.8	0.310	197116.2	0.465	26337	14057	0.095	14436	0.034	22800	0.054	17600	0.042	0.539
14	Shkodra	58270.00	203945	0.720	0.960	0.964	0.964	0.25	0.25	332483	241552	96620.8	0.291	144931.2	0.436	25178	13811	0.117	17512	0.053	19870	0.060	14560	0.044	0.556

where:

I1 – number of employees in the public sector in that city;
I2 – number of employees in enterprises in that city;
I3 – number of pupils in that city;
I4 – number of students in that city;
I5 – number of unemployed in that city;
I6 – number of other population;
P – total population of the city;
W1 – use of ICT and Internet in the public sector;
W2 – use of ICT and Internet in enterprises;
W3 – use of ICT and Internet by pupils;
W4 – use of ICT and Internet by students;
W5 – use of ICT by unemployed;
W6 – use of ICT by others.

3.3 Traffic Calculation for Each City (node) of the Graph

For each city (graph nodes) the calculation of the traffic matrix is based on the number of households, the usage time of the networks and the number of service users in a network. This is calculated according to the following formula *(Al-Wakeel, 2009):*

$$T=P/N \quad (3)$$

where:

T – number of households in the city
P – number of inhabitants in the city
N – number of inhabitants in a house (INSTAT, 2019), *(Office, 2005*), (*Statistic, 2011)*.

The total traffic TE for any city (Table 2) is calculated as:

$$T = \left(C * \frac{P}{N} * \frac{CC * CL}{24} + R * \frac{P}{N} * \frac{CR * RL}{24} \right) \quad (4)$$

where:

C – commercial households (in percent)
CC – number of active on-line sessions per commercial household per day (24 hours)
CL – commercial session duration (in hours)
R – residential households (in percent)
CR – number of active on-line sessions per residential household per day (24 hours)
RL – residential session duration (in hours)

The use of the SEI indicator when calculating traffic for each city reduces by almost 50% and this gives a better picture of the more realistic planning of a WAN network.

$$T = \left(C * \frac{P}{N} * \frac{CC * CL}{24} + R * \frac{P}{N} * \frac{CR * RL}{24} \right) * SEI \quad (5)$$

Table 2. Traffic calculation for each city

Cities	Population	Households N= 3,5 T	CT(15%)	RT(85%)	TC (CT*CL*4)/24, CL=1/2 h	TR (RT*RL*1)/24, RL=1/2 h	All traffic: TC+TR
Struga	63376	18107.43	2716.11	15391.31	226.34	320.65	**547.00**
Manastiri	95385	27252.86	4087.93	23164.93	340.66	482.60	**823.26**
Tetova	86580	24737.14	3710.57	21026.57	309.21	438.05	**747.27**
Shkupi	506926	144836.00	21725.40	123110.60	1810.45	2564.80	**4375.25**
Kumanova	105484	30138.29	4520.74	25617.54	376.73	533.70	**910.43**
Prishtina	477312	136374.86	20456.23	115918.63	1704.69	2414.97	**4119.66**
Prizreni	177781	50794.57	7619.19	43175.39	634.93	899.49	**1534.42**
Gjilani	90178	25765.14	3864.77	21900.37	322.06	456.26	**778.32**
Peja	94450	26985.71	4047.86	22937.86	337.32	477.87	**815.19**
Mitrovica	232833	66523.71	9978.56	56545.16	831.55	1178.02	**2009.57**
Tirana	889578	254165.14	38124.77	216040.37	3177.06	4500.84	**7677.91**
Vlora	126294	36084.00	5412.60	30671.40	451.05	638.99	**1090.04**
Elbasani	276765	79075.71	11861.36	67214.36	988.45	1400.30	**2388.75**
Shkodra	203945	58270.00	8740.50	49529.50	728.38	1031.86	**1760.24**
Σ	3426887						

Table 3. Traffic calculation for each city with SEI

Cities	Population	Households N= 3,5 T	CT(15%)	RT(85%)	TC (CT*CL*4)/24, CL=1/2 h	TR (RT*RL*1)/24, RL=1/2 h	All traffic: TC+TR	SEI	(TC+TR) *SEI
Struga	63376	18107.43	2716.11	15391.31	226.34	320.65	547.00	0.546	**298.47**
Manastiri	95385	27252.86	4087.93	23164.93	340.66	482.60	823.26	0.541	**445.02**
Tetova	86580	24737.14	3710.57	21026.57	309.21	438.05	747.27	0.591	**441.65**
Shkupi	506926	144836.00	21725.40	123110.60	1810.45	2564.80	4375.25	0.585	**2558.74**
Kumanova	105484	30138.29	4520.74	25617.54	376.73	533.70	910.43	0.548	**498.48**
Prishtina	477312	136374.86	20456.23	115918.63	1704.69	2414.97	4119.66	0.667	**2747.81**
Prizreni	177781	50794.57	7619.19	43175.39	634.93	899.49	1534.42	0.565	**866.95**
Gjilani	90178	25765.14	3864.77	21900.37	322.06	456.26	778.32	0.560	**435.86**
Peja	94450	26985.71	4047.86	22937.86	337.32	477.87	815.19	0.560	**456.51**
Mitrovica	232833	66523.71	9978.56	56545.16	831.55	1178.02	2009.57	0.566	**1137.42**
Tirana	889578	254165.14	38124.77	216040.37	3177.06	4500.84	7677.91	0.572	**4391.76**
Vlora	126294	36084.00	5412.60	30671.40	451.05	638.99	1090.04	0.530	**577.72**
Elbasani	276765	79075.71	11861.36	67214.36	988.45	1400.30	2388.75	0.539	**1287.53**
Shkodra	203945	58270.00	8740.50	49529.50	728.38	1031.86	1760.24	0.556	**978.69**
Σ	3426887								

3.4 Calculation of Traffic Between All Cities In The Graph (traffic matrix)

After calculating the traffic for each city, it is necessary to calculate the traffic between all cities (graph nodes) with which the WAN network is described. The traffic between cities A and B is calculated according to the formula *(Al-Wakeel, 2009*):

$$T_{AB} = T_A \times \frac{P_B}{P_T} \tag{6}$$

where:

T_A – the traffic between city A and all other cities;
P_B – number of residents in city B;
P_T – number of all the inhabitants of 14 cities.

In (Table 4) shows that from node (1) Tirana and node (2) Prishtina more traffic is generated. If we disconnect this WAN network from the effects of neighboring networks and consider that these two nodes generate more traffic we will assume that the branch connecting these two nodes is busier with traffic. We now have the opportunity to calculate the Erlang of this branch. Before calculating Erlang it must be known which paths pass through nodes 1 and 2. We find this through algorithms for finding the shortest path.

3.5 Applying the Shortest Path Algorithm To Find Travel Routes

Now we have calculated the traffic of each city (graph nodes) and this is seen in (Table 3) and the traffic of all pairs of cities which is seen in (Table 4) but this again is not enough to know how the branches connecting cities respectively will be loaded with traffic. Packets carrying data will choose the shortest path. The shortest path will be determined by the algorithm for finding the shortest path between all pairs of graph peaks, respectively cities that are in the WAN network. For this case we used the Floyd-Warshal Algorithm (Table 5). The Floyd-Warshall algorithm can be applied in the

Table 4. Traffic calculation between all cities

	Cityes	Households	Populationa	w1	w2	w3	w4	w5	w6	N	employees	I1		I2		I3			I4		I5		I6		SEI
				level of the republic								no. public sector (40%)	$a_1=I_1/N$	no.business sector (60%)	$a_2=I_2/N$	elementary students	High School students	$a_3=I_3/N$	no. students	$a_4=I_4/N$	no. Unemployed	$a_5=I_5/N$	no. Other	$a_6=I_6/N$	
1	Struga	18107.43	63376	0.720	0.960	0.964	0.964	0.25	0.25	63376	47811	19124.4	0.302	28686.6	0.453	6006	3229	0.146	0	0	3034	0.048	3296	0.052	0.546
2	Manastiri	27252.86	95385	0.720	0.960	0.964	0.964	0.25	0.25	95385	66955	26782	0.281	40173	0.421	7421	4604	0.126	2973	0.031	6838	0.072	6594	0.069	0.541
3	Tetova	24737.14	86580	0.720	0.960	0.964	0.964	0.25	0.25	86580	41528	16611.2	0.192	24916.8	0.288	10114	9795	0.230	6670	0.077	9761	0.113	8712	0.101	0.591
4	Shkupi	144836.00	506926	0.720	0.960	0.964	0.964	0.25	0.25	506926	347236	138894.4	0.274	208341.6	0.411	53586	27692	0.160	32911	0.065	15874	0.031	29627	0.058	0.585
5	Kumanova	30138.29	105484	0.720	0.960	0.964	0.964	0.25	0.25	105484	68606	27442.4	0.260	41163.6	0.390	11303	6514	0.169	1732	0.016	6472	0.061	10857	0.103	0.548
6	Prishtina	136374.86	477312	0.720	0.960	0.964	0.964	0.25	0.25	209554	70517	28206.8	0.135	42310.2	0.202	30517	11083	0.199	55731	0.266	18706	0.089	23000	0.110	0.667
7	Prizreni	50794.57	177781	0.720	0.960	0.964	0.964	0.25	0.25	186860	130787	52314.8	0.280	78472.2	0.420	24059	7691	0.170	4253	0.023	10200	0.055	9870	0.053	0.565
8	Gjilani	25765.14	90178	0.720	0.960	0.964	0.964	0.25	0.25	88307	48883	19553.2	0.221	29329.8	0.332	12917	5198	0.205	2805	0.032	9650	0.109	8854	0.100	0.560
9	Peja	26985.71	94450	0.720	0.960	0.964	0.964	0.25	0.25	99154	53368	21347.2	0.215	32020.8	0.323	13639	4935	0.187	5432	0.055	11230	0.113	10550	0.106	0.560
10	Mitrovica	66523.71	232833	0.720	0.960	0.964	0.964	0.25	0.25	72597	40048	16019.2	0.221	24028.8	0.331	11679	4240	0.219	1923	0.026	7821	0.108	6886	0.095	0.566
11	Tirana	254165.14	889578	0.720	0.960	0.964	0.964	0.25	0.25	997380	725036	290014.4	0.291	435021.6	0.436	57454	39890	0.098	94500	0.095	45000	0.045	35500	0.036	0.572
12	Vlora	36084.00	126294	0.720	0.960	0.964	0.964	0.25	0.25	374168	291304	116521.6	0.311	174782.4	0.467	17598	10366	0.075	15000	0.040	23000	0.061	16900	0.045	0.530
13	Elbasani	79075.71	276765	0.720	0.960	0.964	0.964	0.25	0.25	423757	328527	131410.8	0.310	197116.2	0.465	26337	14057	0.095	14436	0.034	22800	0.054	17600	0.042	0.539
14	Shkodra	58270.00	203945	0.720	0.960	0.964	0.964	0.25	0.25	332483	241552	96620.8	0.291	144931.2	0.436	25178	13811	0.117	17512	0.053	19870	0.060	14560	0.044	0.556

specific graph where the nodes are represented as cities or routers and the distance is represented as the weight of the branches or links.

Let A_k be a matrix of type nxn, where A_k [i, j] is the weight of the shortest path from i to j, which passes through nodes <= k. For this case we define:

$$A_0 i, X = \begin{cases} 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots IF\, i = j \\ the\, weight\, of\, the\, branches\, from\, i\, to\, j \ldots FOR\, i \neq j\, AND\left(i, j\right) \in E \\ \infty \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots IF i \neq j AND\left(i, j\right) \notin E \end{cases} \qquad (7)$$

We examine the shortest path p from i to j, which passes through nodes 1...k. One of two possibilities applies to the path p:

The path p does not pass through k and in this case the path is A_{k-1} [i, j].

The path p passes through k and in this case the weight of the path is A_{k-1}[i, k]+A_{k-1}[k,j] *(Cormen, Introduction to Algorithms, 2009*). In (Table 5) shows the beginning of the application of the Floyd-Warshall algorithm for the graph and after the calculations in (Table 6) the final results are seen.

The road passes or does not pass through the branch Tirana (1) - (2) Prishtina is determined by the shortest road (Table 7). All of these will be collected and than the Erlang in that branch will be calculated.

3.6 Erlang Calculation At The Branches

In this planned WAN network the branch that connects two cities (nodes) with the highest number of population where more traffic is generated is assumed to represent a backbone. In the branch which connects the two most important nodes we can calculate Erlang between nodes 1-10-2 Tirana-Prizren-Prishtina (Table 8). Erlang of a branch includes traffic not only of the nodes that connects this branch but also traffic of other nodes that the road passes through this branch according to the algorithm for finding the shortest path.

Table 5. Flloyd-Warshall algorithm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	∝	∝	∝	146	∝	∝	∝	∝	135	∝	114	22	115
2	∝	0	113	∝	∝	∝	∝	35	24	35	∝	∝	∝	∝
3	∝	113	0	120	35	∝	28	∝	∝	∝	∝	∝	∝	∝
4	∝	∝	120	0	130	58	∝	∝	∝	∝	∝	∝	∝	∝
5	146	∝	35	130	0	113	∝	∝	∝	19	∝	∝	∝	∝
6	∝	∝	∝	58	113	0	∝	∝	∝	∝	∝	∝	50	∝
7	∝	∝	28	∝	∝	∝	0	58	∝	∝	∝	∝	∝	∝
8	∝	35	∝	∝	∝	∝	58	0	∝	∝	∝	∝	∝	∝
9	∝	24	∝	∝	∝	∝	∝	∝	0	∝	47	∝	∝	∝
10	135	35	∝	∝	19	∝	∝	∝	∝	0	38	∝	∝	∝
11	∝	∝	∝	∝	∝	∝	∝	∝	47	38	0	64	∝	∝
12	114	∝	∝	∝	∝	∝	∝	∝	∝	∝	64	0	∝	∝
13	22	∝	∝	∝	∝	50	∝	∝	∝	∝	∝	∝	0	122
14	115	∝	∝	∝	∝	∝	∝	∝	∝	∝	∝	∝	122	0

Table 6. Final results of Floyd-Warshall Algorithm application

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	170	181	130	146	72	209	205	194	135	173	114	22	115
2	170	0	89	184	54	167	93	35	24	35	71	135	192	285
3	181	89	0	120	35	148	28	86	113	54	92	156	198	296
4	130	184	120	0	130	58	148	206	208	149	187	244	108	230
5	146	54	35	130	0	113	63	89	78	19	57	121	163	261
6	72	167	148	58	113	0	176	202	191	132	170	186	50	172
7	209	93	28	148	63	176	0	58	117	82	120	184	226	324
8	205	35	86	206	89	202	58	0	59	70	106	170	227	320
9	194	24	113	208	78	191	117	59	0	59	47	111	216	309
10	135	35	54	149	19	132	82	70	59	0	38	102	157	250
11	173	71	92	187	57	170	120	106	47	38	0	64	195	288
12	114	135	156	244	121	186	184	170	111	102	64	0	136	229
13	22	192	198	108	163	50	226	227	216	157	195	136	0	122
14	115	285	296	230	261	172	324	320	309	250	288	229	122	0

3.7 Bandwidth Calculation In Main Branches (Backbone)

If Erlang is known for a corresponding branch of a graph one can easily calculate the Bandwidth of that branch. This is done so that the Erlang now calculated as scalar multiplied by 64000 (bps) and Bandwidth is obtained. For the branch which in this case represents the Backbone of the intended WAN network is Tirana (1) - (2) Prishtina we have a bandwidth of 178.71 Mbps (Table 9).

Table 7. Shortest path between Nodes

Node1	Node2	Distance	Route with shortest path (Floyd- Warshal)
Tirana(1)	(2)Prishtina	170	Tirana-Prizreni-Prishtina
Tirana(1)	(3) Shkupi	181	Tirana-Tetova-Shkupi
Tirana(1)	(4) Manastiri	130	Tirana-Elbasani-Struga-Manastiri
Tirana(1)	(5) Tetova	146	Tirana-Tetova
Tirana(1)	(6) Struga	72	Tirana-Elbasani-Struga
Tirana(1)	(7) Kumanova	209	Trana-Tetova-Shkupi-Kumanova
Tirana(1)	(8) Gjilani	205	Tirana-Prizreni-Prishtina-Gjilani
Tirana(1)	(9) Mitrovica	194	Tirana-Prizreni-Prishtina-Mitrovica
Tirana(1)	(10) Prizreni	135	Tirana-Prizreni
Tirana(1)	(11) Peja	173	Tirana-Prizreni-Peja
Tirana(1)	(12) Shkodra	114	Tirana-Shkodra
Tirana(1)	(13) Elbasani	22	Tirana-Elbasani
Tirana(1)	(14) Vlora	115	Tirana-Vlora
Prishtina(2)	(3) Shkupi	89	Prishtina-Prizreni-Tetova-Shkupi
Prishtina(2)	(4) Manastiri	184	Prishtina-Prizreni-Tetova-Manastiri
Prishtina(2)	(5) Tetova	54	Prishtina-Prizreni-Tetova
Prishtina(2)	(6) Struga	167	Prishtina-Prizreni-Tetova-Struga
Prishtina(2)	(7) Kumanova	93	Prishtina-Gjilani-Kumanova
Prishtina(2)	(8) Gjilani	35	Prishtina-Gjilani
Prishtina(2)	(9) Mitrovica	24	Prishtina-Mitrovica
Prishtina(2)	(10) Prizreni	35	Prishtina-Prizreni
Prishtina(2)	(11)Peja	71	Prishtina-Mitrovica-Peja
Prishtina(2)	(12) Shkodra	135	Prishtina-Mitrovica-Peja-Shkodra
Prishtina(2)	(13) Elbasani	192	Prishtina-Prizreni-Tirana-Elbasani
Prishtina(2)	(14) Vlora	285	Prishtina-Prizreni-Tirana-Vlora
Shkupi(3)	(4) Manastiri	120	Shkupi-Manastiri
Shkupi(3)	(5) Tetova	35	Shkupi-Tetova
Shkupi(3)	(6) Struga	148	Shkupi-Tetova-Struga
Shkupi(3)	(7) Kumanova	28	Shkupi-Kumanova
Shkupi(3)	(8) Gjilani	86	Shkupi-Kumanova-Gjilani
Shkupi(3)	(9) Mitrovica	113	Shkupi-Tetova-Prizreni-Prishtina-Mitrovica
Shkupi(3)	(10) Prizeni	54	Shkupi-Tetova-Prizreni
Shkupi(3)	(11) peja	92	Shkupi-Tetova-Prizreni-Peja
Shkupi(3)	(12) Shkodra	156	Shkupi-Tetova-Prizreni-Peja-Shkodra
Shkupi(3)	(13) Elbasani	198	Shkupi-Tetova-Struga-Elbasani
Shkupi(3)	(14) Vlora	296	Shkupi-Tetova-Tirana-Vlora
Manastiri(4)	(5) Tetova	130	Manastiri-Tetova
Manastiri(4)	(6) Struga	58	Manastir-Struga
Manastiri(4)	(7) Kumanova	148	Manastiri-Shkupi-Kumanova
Manastiri(4)	(8) Gjilani	206	Manastiri-Shkupi-Kumanova-Gjilani
Manastiri(4)	(9) Mitrovica	208	Manastiri-Tetova-Prizreni-Prishtina-Mitrovica
Manastiri(4)	(10) Prizreni	149	Manastiri-Tetova-Prizreni
Manastiri(4)	(11) Peja	187	Manastiri-Tetova-Prizreni-Peja
Manastiri(4)	(12) Shkodra	244	Manastiri-Struga-Elbasani-Tirana-Shkodra
Manastiri(4)	(13) Elbasani	108	Manastiri-Struga-Elbasani
Manastiri(4)	(14) Vlora	230	Manastiri-Struga-Elbasani-Vlora
Tetova(5)	(6) Struga	113	Tetova- Struga
Tetova(5)	(7) Kumanova	63	Tetova-Shkupi-Kumanova
Tetova(5)	(8) Gjilani	89	Tetova-Prizreni-Prishtina-Gjilani
Tetova(5)	(9) Mitrovica	78	Tetova-Prizreni-Prishtina-Mitrovica
Tetova(5)	(10) Prizreni	19	Tetova-prizreni

continued on folowing page

Table 7. Continued

Node1	Node2	Distance	Route with shortest path (Floyd- Warshal)
Tetova(5)	(11) Peja	57	Tetova-Prizreni-Peja
Tetova(5)	(12) Shkodra	121	Tetova-Prizreni-Peja-Shkodra
Tetova(5)	(13) Elbasani	163	Tetova-Struga-Elbasani
Tetova(5)	(14) Vlora	261	Tetova-Tirana-Vlora
Struga(6)	(7) Kumanova	176	Struga-Tetova-Shkupi-Kumanova
Struga(6)	(8) Gjilan	202	Struga-Tetova-Prizreni-Prishtina-Gjilani
Struga(6)	(9) Mitrovica	191	Struga-Tetova-Prizreni-Prishtina- Mitrovica
Struga(6)	(10) Prizreni	132	Stuga-Tetova-Prizreni
Struga(6)	(11)Peja	170	Stuga-Tetova-Prizreni-Peja
Struga(6)	(12) Shkodra	186	Struga-Elbasani-Tirana-Shkodra
Struga(6)	(13) Elbasani	50	Struga-Elbasan
Struga(6)	(14) Vlora	172	Struga-Elbasani-Vlora
Kumanova(7)	(8) Gjilan	58	Kumanova-Gjilani
Kumanova(7)	(9) Mitrovica	117	Kumanova –Gjilani-Mitrovica
Kumanova(7)	(10) Prizreni	82	Kumanova-Shkupi-Tetova-Prizreni
Kumanova(7)	(11)Peja	120	Kumanova-Shkupi-Tetova-Prizreni-Peja
Kumanova(7)	(12) Shkodra	184	Kumanova-Shkupi-Tetova-Prizreni-Peja-Shkodra
Kumanova(7)	(13) Elbasani	226	Kumanova-Shkupi-Tetova-Struga-Elbasani
Kumanova(7)	(14)Vlora	324	Kumanova-Shkupi-Tetova-Tirana-Vlora
Gjilani(8)	(9) Mitrovica	59	Gjilani-Prishtina-Mitrovica
Gjilani(8)	(10) Prizreni	70	Gjilan-Prishtina-Prizreni
Gjilani(8)	(11) Peja	106	Gjilani-Prishtina-Mitrovica-Peja
Gjilani(8)	(12) Shkodra	170	Gjilani- Prishtina-Mitrovica-Peja-Shkodra
Gjilani(8)	(13) Elbasani	227	Gjilani-Prishtina-Prizreni-Tirana-Elbasani
Gjilani(8)	(14) Vlora	320	Gjilani-Prishtina-Prizreni-Tirana-Vlora
Mitrovica(9)	(10) Prizreni	59	Mitrovica-Prishtina-Prizreni
Mitrovica(9)	(11) Peja	47	Mitrovica-Peja
Mitrovica(9)	(12) Shkodra	111	Mitrovica-Peja-Shkodra
Mitrovica(9)	(13) Elbasani	216	Mitrovica-Prishtina-Prizreni-Tirana-Elbasani
Mitrovica(9)	(14) Vlora	309	Mitrovica-Prishtina-Prizreni-Tirana-Vlora
Prizreni(10)	(11) Peja	38	Prizreni-Peja
Prizreni(10)	(12) Shkodra	102	Prizreni-Peja-Shkodra
Prizreni(10)	(13) Elbasan	157	Prizreni-Tirana-Elbasani
Prizreni(10)	(14) Vlora	250	Prizreni-Tirana-Vlora
Peja(11)	(12) Shkodra	64	Peja-Shkodra
Peja(11)	(13) Elbasani	195	Peja-Prizreni-Tirana-Elbasani
Peja(11)	(14)Vlora	288	Peja-Prizreni-Tirana-Vlora
Shkodra(12)	(13) Elbasani	136	Shkodra-Tirana-Elbasani
Shkodra(12)	(14) Vlora	229	Shkodra-Tirana-Vlora
Elbasani(13)	(14) Vlora	122	Elbasani-Vlora

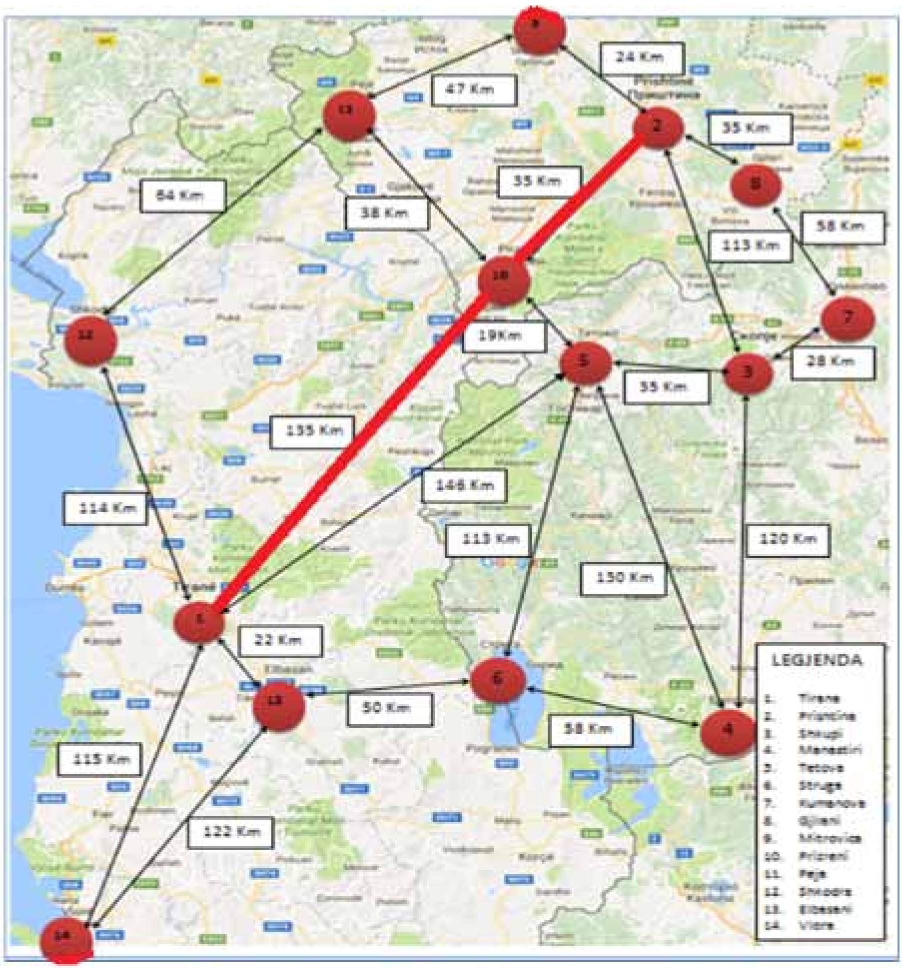
Table 8. Traffic (in Erlangs): Tirana(1)-(2)Prishtina

Nodes	Shortest Path (km)	Rout	Communication (with SEI included)
Tirana(1)- (2) Prishtina	170	Tirana-Prizreni-Prishtina	713.30
Tirana(1)-(8) Gjilani	205	Tirana-Prizreni-Prishtina-Gjilani	113.14
Tirana(1)-(9) Mitrovica	194	Tirana-Prizreni-Prishtina-Mitrovica	295.3
Tirana(1)- (10) Prizreni	135	Tirana-Prizreni	225.1
Tirana(1)- (11) Peja	173	Tirana-Prizreni-Peja	118.5
Prishtina(2)-(4)Manastiri	184	Prishtina-Prizreni-Tetova-Manastiri	61.98
Prishtina(2)- (5) Tetova	54	Prishtina-Prizreni-Tetova	61.52
Prishtinë(2)-(6) Struga	167	Prishtina-Prizreni-Tetova-Struga	41.57
Prishtina(2)-(10) Prizreni	35	Prishtina-Prizreni	142.6
Prishtina(2)-(13) Elbasani	192	Prishtina-Prizreni-Tirana-Elbasani	221.92
Prishtina(2)- (14) Vlora	285	Prishtina-Prizreni-Tirana-Vlora	101.3
Shkupi(3)-(9) Mitrovica	113	Shkupi-Tetova-Prizreni-Prishtina-Mitrovica	173.8
Manastiri(4)-(9)Mitrovica	208	Manastiri-Tetova-Prizreni-Prishtina-Mitrovica	30.24
Tetova(5)- (8) Gjilani	89	Tetova-Prizreni-Prishtina-Gjilani	11.62
Tetova(5)-(9) Mitrovica	78	Tetova-Prizreni-Prishtina-Mitrovica	30.01
Struga(6)- (8) Gjilani	202	Struga-Tetova-Prizreni-Prishtina-Gjilani	7.85
Struga(6)- (9) Mitrovica	191	Struga-Tetova-Prizreni-Prishtina-Mitrovica	20.28
Gjilani(8)- (10) Prizreni	70	Gjilan-Prishtina-Prizreni	22.8
Gjilani(8)-(13) Elbasani	227	Gjilani-Prishtina-Prizreni-Tirana-Elbasani	35.20
Gjilani(8)- (14) Vlora	320	Gjilani-Prishtina-Prizreni-Tirana-Vlora	16.06
Mitrovica(9)-(10) Prizreni	59	Mitrovica-Prishtina-Prizreni	58.9
Mitrovica(9)-(13) Elbasani	216	Mitrovica-Prishtina-Prizreni-Tirana-Elbasani	91.86
Mitrovica(9)- (14) Vlora	309	Mitrovica-Prishtina-Prizreni-Tirana-Vlora	41.92
Prizreni(10)-(13) Elbasan	157	Prizreni-Tirana-Elbasani	70.01
Prizreni(10)- (14) Vlora	250	Prizreni-Tirana-Vlora	31.95
Peja(11)- (13) Elbasani	195	Peja-Prizreni-Tirana-Elbasani	36.87
Peja(11)-(14)Vlora	288	Peja-Prizreni-Tirana-Vlora	16.82
TIRANA-PRISHTINA (Erlangs)			**2792.42**

Table 9. Bandwidth calculation in Backbone Tirana(1)-(2)Prishtina

Branches of graph	ERLANG (Traffic)	Bandwidth(bps)	Kbps	Mbps
Tirana(1)-(2) Prishtina	2792.42	2792.42*64000(bps)= 178714880 bps	178714.88 Kbps	178.71 Mbps

Figure 2. Bandwidth in Backbone Tirana-Prishtina 178.71 Mbps



Bandwidth = Erlang*64 kbps (8)

If the simulated network graph is located in the middle of a graph of other regional networks, it should also be considered because the simulated graph branches can be loaded with traffic from other WAN nodes as well. If the effects of neighbor's networks are excluded, the bandwidth calculated in the Tirana (1) - (2) Prishtina branch is 178.71 Mbps (Figure 2).

4. CONCLUSION

Calculating the bandwidth for the branches of a graph describing a regional network is essential because it must meet the requirements and also the cost of bulding that network must be reasonable. For this a calculation and planning must be done. Then, based on this planning, a network with adequate performance is built. This is not an easy task. Branches that are busy with traffic are the backbone of a regional WAN network. The placement of equipment in these branches must be in accordance with the traffic passing through these branches. In this paper is considered a case of a regional WAN network in which the width of a main backbone branch is calculated. The well-known method (*Al-Wakeel, 2009)* which includes some parameters taken from the area where the regional network should operate, such as: creation of graphs, number of families, number of network users, total traffic for each city, matrix of traffic between all cities, assigning the shortest route between all pairs of graph nodes. In this paper, a parameter is added to this method, ie the socio-economic indicator SEI. With the application of SEI, an even more accurate calculation of the traffic in the nodes (cities) of the network graph is made. This is seen in table 3, in which with the application of SEI we have a greater accuracy of calculating traffic so we have halving it in each node (city). Now the planning is in line with these calculations. If the impact of traffic from other networks is excluded, the traffic in Erlang will be the amount of traffic generated by the two end nodes of the branch and in addition the traffic of other roads passing through that branch. Bandwidth for that branch will be obtained if Erlang is multiplied by the unit 64000 bps.

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