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NETWORK SLICING WITH E2E LATENCY

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Abstract

Network function virtualization is a promising solution for providing numerous services with varying characteristics and capabilities in 5G and beyond networks. At the same time, you must meet all of the conditions. Each service, in its way, Follows a set of instructions in particular. The service is excellent. A function chain (SFC) is a collection of routines that run on a computer. the cloudy atmosphere Various service slices to be made in good working order It's crucial to select the appropriate music. for the appropriate mood To install the features in the SFC, follow the steps below. The SFC requires cloud nodes to route them flexibly. the service flow that makes it possible for certain functions to be performed processed In, the end-to-end path is followed. In the appropriate SFC, a sequence is defined. All services are available. Latency limits (E2E) are guaranteed. budget cloud and communication resources have constraints. respected.

I. INTRODUCTION

Network function virtualization is an important technology for the fifth generation (5G) and beyond.B5G (beyond 5G) networks (NFV). As opposed to the networks where specialized service operations are the norm fixed NFV can be effectively replaced with processed NFV. Cloud technology can be used to set up some gear. network nodes with unique settings that process network traffic on-demand service functions, and then construct a flexible environment for each service request on the network, a virtual environment is created. network NFV-enabled networks NFV-enabled networks NFV-enabled networks NFV-enabled networks NFV-enabled networks NFV-enabled networks traditional networking is combined with network nodes. nodes. Each service is made up of several nodes (cloud nodes) as well as a collection of services The functions of a virtual network in a [3], [5], referred to as the predefined order (VNFs). SFC stands for service function chain.Node (computational) capability is limited. Without taking into account the restricting link/node capacity constraints in the [12] and [13] solutions,Depending on how the problem is phrased, it may result in resource allocation.constraints. infringements [14] were found on a shared site.investigated as a source of Virtual Network Functions (VNFs) and Traffic Flow Routing. It was a battle between the data centers that host the VNFs and called for a reduction in the number of VNFs.due to deployed VNFs' latency constraints [15] [4] discussed that the activity related status data will be communicated consistently and shared among drivers through VANETs keeping in mind the end goal to enhance driving security and solace. Along these lines, Vehicular specially appointed systems (VANETs) require safeguarding and secure information correspondences..

(B) What We've Done

In this paper, we present two new mathematical formulations of the network slicing problem that take into account the demand for E2E latency, the resource budget, and the flow at the same time, routing and functional instantiation are performed. The most crucial

• First, we present a mixed binary linear model that incorporates traffic routing flexibility into the equation. formulation (MBLP) of programming in [21]. formulation (MBLP) of programming in(NS-I)ahead), which is natural (in terms of its nature). traditional solvers) and can be solved by design Gurobi [30] is an example of a variable. The issue is stated as follows: in such a way that the weighted average of the results is minimized overall power usage of the system across the entire cloud network(equivalent to the number of cloud servers in total)nodes in the cloud that have been deployed) as well as the overall latency of all of them based on the services

II. DEFINITION OF THE PROBLEM

Consider the directed network G = I, L, where I = I is the initial condition. The total number of nodes in a network. The collection of linkages L = I j) The set of nodes is N = I j). Each connection must be active. Ci is the upper limit on the total data rate I j), and j is the lower limit on the total data rate I j).capacity. As a result, the queuing delay for each link has increased.[31] can be presumed to be insignificant. As a result, we can assume that each link's projected value is the same. delay (in the communication) She has a long propagation delay. Let V, often known as a constant di, j [14], [21], [32], be equal to assign a subset of I to the collection of cloud nodes. Each cloud is unique. Node v has its own set of rules.

capacity v, and we assume that each unit is processed only once, as in [6,]

One unit of (normalized) processing power is required for each unit of data rate capacity. A set of flows K = k is supported by the network. Let S(k) and D(k) be the flow's source and destination nodes, respectively. k, and presume that S(k), D(k) = V /. Each one has its flow .k refers to a specific service provided by an SFC consisting of a set of k service functions that must be completed in order of the network: f k 1 (f) k f ffffffffffffff k

B. A Demonstration of the Problem of Network Slicing

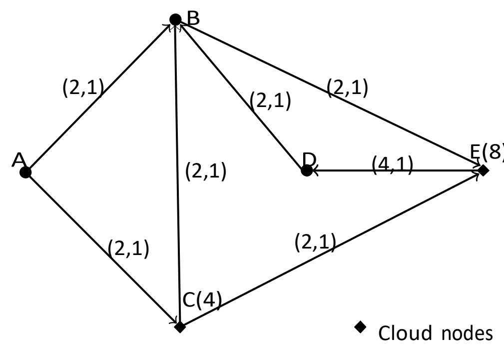
The goal of the network slicing challenge is to assign resources to different parts of the network. all service functions that use a common network infrastructure for a network to create a functional environmental flow, routes, and associated data are created utilizing rates of all flows on the cloud and communication resources appropriate paths to suit a variety of service needs It's vital to come up with a good answer. to devise a problem-solving strategy that incorporates everyone number of practical issues, including the ability to be adaptable flexible routing and E2Edelay are taken into account in routing and E2Edelay.such as those used in [9], and [10] allow traffic to move freely.to select from a variety of choices as well as their paths on the corresponding paths, the data rates associated with them

(a, b) for each link: for this link, the link capacity is a and the communication delay is b. (c) For each node, the communication delay is b and the link capacity is this nexus The node's capacity is c. A network is depicted in Figure 1 as an example.

Traffic flows can be routed in several different ways.

Multiple paths are possible, which mitigates the effects of (low)On the network slicing problem. It is critical to have adequate connectivity capacity. Assume there is only. one service that connects nodes A and D The E2E (End-to-End)1 = 5 is the delay threshold. The SFC is considered. All 0(1), 1(1), and 2(1) service functions, as well as account.f1 and f2.There are four of them in two (1). If there was only one, is a transmission path that is allowed, but there is no solution for traffic flow.(For example, [7], [15], [21], and [22]).exists in this situationbecause4 The E2E latency limitation for each service is not the same imposed (as in [9], and [10]). The most appropriate response is for both of them must collaborate.

Service I (offering function f) A B EThe second service is D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D,D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D B) 2)((((((((((((((((((((((((((It takes four connections to get from node A to node B.With a total transmission delay of four, service IIwhen paired with the requirement for E2E latencyAs a result, to arrive at a better solution, NFV delay 1 has been violated. the solution, E2Elatency constraints are stated explicitly in the formulation of theproblem Then there's the matter of the E2E problem.Latency constraints are as follows: A B A B A B A B A B A B A B A B A B A B A B A B A B A B A B A B A B AA B A B A B A B A B A B A B A B A B A B A



III. FORMULATION OF THE PROBLEM

A. A Sneak Peek at the Problem Formulation

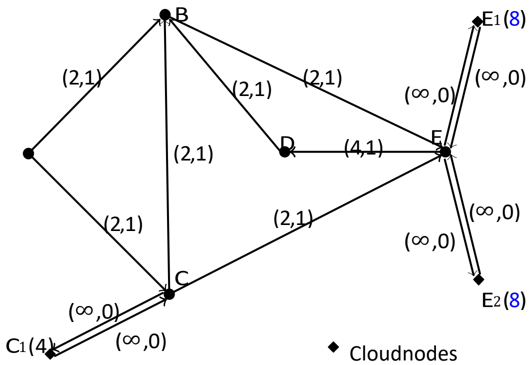
The goal of the network slicing problem is to figure out how to slice a network. all flows and routes are functionally instantiated when calculating the related data rates of all flows on the routes the E2E delay and meeting the SFC criteria requirements, as well as the capacity limits that all cloud services face. There are two types of nodes and links. We'll introduce a new section in this part. The network slicing problem is formulated as a problem. which considers issues such as flexible routing and E2Etake latency needs into account; see the issue(NS-I) is a step ahead. The formulation we offer is based on those in two related publications [21] and [10], however, takes further steps To be more specific, in contrast, to the formulation in [21], in which just one path is considered permitted to route

Various Constraints (B)

This section will go over the many limitations of the network slicing problem. Before we get started, there are a few things we need to take care of. the first one to arrive. a virtual network identical to the one that exists previously said, it is critical in exposing the limitations.

• A Virtual Network That Is Equivalent to a Physical Network

Each cloud node in the physical network can only handle one function, according to the references [33], and [34].of the same stream As a result of this assumption, several things have happened. There are possibilities available. The functions of each flow must be understood. hosted on several cloud nodes As a result, the number of newcomers has increased.Cloud nodes mayl grow. must be activated (and hence the cloud network's energyconsumption), and (in the cloud network)the total communication delays flow (as the flow needs to traverse more links). As a result, in this case, we do not make such an assumption. paper, i.e. the ability to process a variety of functions cloud node that is the same from the same flow



In the virtual network, C and E are no longer cloud nodes; the capacity of cloud nodes E1 and E2 should not exceed the capacity of node E in the physical network for each flow. A cloud node can process a function. (maybe)linked with various functionalities of the same virtual network flow can be processed by any cloud node in the system. Physical network which is critical in cutting the costs the number of nodes that must be enabled and the amount of time it will take it takes to accomplish this The overall performance of a physical network and the time it takes for a communication to happen is calculated.

The problem's NP-hardness (NS-I) and size are both high

Due to a vast number of variables and limitations, the above is the case. Only the issue of tiny size can be solved. This method was used to fix the problem. We'll give you a quote. In the following section, you'll find an alternative. a recipe containing a lot of third, if there are fewer variables as well as a limitation the power consumption phrase is used, or if the power consumption word is used, term, or if the power consumption term, or if the power consumption term, or if the power consumption term, or if the power consumption term, or if the phrase of consumption, or a term of power consumption, The total number of cloud nodes that have been deployed. The total delay is less essential in the activated stateterm objective function (in which only the second term is used)functions as a regularizer), and the issue is reduced to a single variable. two-steps(k) v, s(k) v, s(k) v, s(k) v, s(k) v, s(k) v, s(k) v, s(k) v, s(k) v, s(k) (k). (5)We can calculate the node's (normalized) computation capabilities since processing one unit of data rate takes one unit of energy. The capacity limits are as follows: X k X s F(k) X k X s X k X s X k X s X ks(k)x0v,s(k) v y v, vV. v, s(k) v y v, v V. v, s(k) v y v, v V. (6)The total number of cloud nodes that have been turned on should be larger than or equal to the total (physically). Every service is required to have data rates. After that, there's Xv Vv.0 v v y v v y v v y v v y v v y v v y v v y v v y v v y v v y v v y v v y v vX s ssssssss (k)

• Constraints on link capacity and flexible routing

In practice, each flow k should be injected into the cloud nodes in the order in which the functions in it are listed in the flow. SFC, from the source node S(k) to the destination node D is the final destination node (k). To express the ebb and flow of events Use (k, s, vs, vs+1) when routing between (k, s, vs, vs+1).We know that link I j) is on the p-the flow path (k, s, vs, vs+1).Use zi, j (k, s, vs, vs+1, p) = 1 if zi, j (k, s, vs, vs+1, p) = 1 if zi, j (k, s, vs, vs+1, p) = 1 if zi,j (k, s, vs, vs+1, p)p) equals 0. By definition, for any k p PI j) L and I j) L are the two options .X vs. s,s (kxvs+1,s+1 z I,j (k, s, vs, vs+1, p) xv s xv s xv s xv s xv s xv s xv s xv s xv s xv s,s(k)xvs+1,s+1 (k),s F(k)'k,s F(k)'k,s F(k)'k,s F(k)'k,s F(k)'k

To begin, keep in mind that data rate flow conservation restrictions (18), (19), and (20) apply. Second, three additional flow conservation requirements (21), (22), and (23) are imposed (23)are necessary. To be more precise, for each cloud couple vs and vs+1 nodes, with constraints (21), (22), and (23). (23). (23), All we have to do now is evaluate the circumstance in which xv s, s (k) Since constraint (11) is satisfied, xvs+1,s+1(k) = 1. All of the variables zi, j (k, s, vs, vs, vs, vs, vs, vs, vs, vs, vs, vs, vs, vs, versus. The variables vs+1 and p) must be equal.be the same as the constraint of zero (22)ensures that each node is in this state. that isn't true and ks+1 if one of the incoming messages is a function. One connection is assigned to the p-the flow path (k, s, vs, vs+1), and the other is assigned to the p-the flow path (k, s, vs, vs+1).

The problem's NP-hardness (NS-I) and size are both high.

Due to a vast number of variables and limitations, the above is the case. Only the issue of tiny size can be solved. This method was used to fix the problem. We'll give you a quote. In the following section, you'll find an alternative. a recipe containing a lot of third, if there are fewer variables as well as a limitation If the power consumption phrase is used, or if the power consumption word is used, term, or if the power consumption term, or if the power consumption term, or if the power consumption term, or if the power consumption term, or if a phrase of consumption, or a term of power consumption, The total number of cloud nodes that have been deployed. The total delay is less essential in the activated state. term objective function (in which only the second term is used)functions as a regularizer), and the issue is reduced to a single variable. two-step

IV. A SIMPLE SOLUTION TO THE PROBLEM

In this section, we will design a compact problem formulation for the network slicing problem, which includes a large number of variables. There are a lot fewer variables and constraints. We'll show that the new formulation is, in reality, the same as the old one identical to the formulation

TABLE II
SUMMARY OF NEW VARIABLES IN PROBLEM (NS-II

$r(k,s,p)$	the thethethethe data rate on the p-the path of flow (k,s) that is f_s^k and f_{s+1}^k used to route the traffic flow between the two (virtual) cloud nodes hosting functions, respectively
$I_{,j}(k,s,p)$	binary variable indicating whether or not link (i,j) is on the p-the path of flow (k,s)
$RI_{,j}(k,s,p)$	The data on the link (i,j) which is used by the p-there path of flow (k,s)

• Important New Constraints and Notations A. In a Novel Approach to Problem-solving the new version uses the same placement variables. xv,s(k), and x 0 is the same formulation as in problem (NS-I).iv, v, s(k), and v As a result, we apply the same restrictions.(2) to (7) in the all-new formula In addition, these delay variables (k, s) are the same, and the terms N (k) L(k), and L(k) are also employed. As a result, restrictions (37)- are imposed. (39) is likewise enforced in the amended formulation. However, in the instance of employing different variables to solve a problem, Each flow k's traffic is represented by a flow. Then we'll go on to the next step. Discuss the new variables that will be used to represent the data. Remember the ebbs and flows, as well as the constraints that come with them. how (k, s, vs, vs+1) were used

The new formulation's flow conservation constraints are then supplied to ensure that each flow's functions are kept .processed in the order in which it was specified in (1). Let's start with the basics .The flow conservation constraints of the intermediate functions of each flow For each k K, s F(k)'k, s F(k)'k, s F(k)'k, s F(k)'k, s F(k)'k, s F(k)'k, s F(k)'k, s F(k)'kF(k)'k, s F(k)'k, s F(We have p p and I I and we have p p and I I and we have p p and I I and we have p p and I I and we have p p and I Irj,i(k, s, p) rj,i(k, s, p) rj,i(k, s, p) rj,i(k, s, p) rj,i(k, s, p) (k, s, p)rj,i(k, s,Xj:(i,j)L rj,i(k, s,Xj:(i,j)Lri,j (k, s, p) = 0 if I I V, ri,j (k, s, p) = 0. (47)If I V, ri,N(i)(k, s, p) = r(k, s, p)xi,s(k); if I V, ri,N(i)(k, s, p) = r(k, s, p)xi,s(k); (48)If I V, rN(i),i(k, s, p) = r(k, s, p)xi,s+1(k); if I V, rN(i),i(k, s, p) = r(k, s, p)xi,s+1(k); (49)Xj:(j,i)L zj,i(k, s, p) zj,i(k, s, p) zj,i(k, s, p) zj,i(k, s, p) zj,i(k, s, p) zj,i(k, s, p) zj,i(k,s,Xj:(i,j)L if I I V; zi,j (k, s, p) = 0; zi,j (k, s, p) = 0; zi,j (k, s, p) = 0; zi,j (k, s, p) = (50)If I V, zi,N(i)(k, N(i)(k, N(i)(k, N(i)(ks

• A New, more compact problem formulation

The new network slicing issue formulation is now available:((

((s.t. s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t.s.t. s.t

(64.) (NS-II)

The problem (NS-II) is also an issue because of the nonlinearity.

MBL P .r(k, s, p)xi ,s(k), r(k, s, p)xi,s+1(k), r(k, s, p)xi ,s(k), r(k, s, p)xi ,s(k), r(k, s, p)xi, s(k), r(k, s, p)xi ,s(k) (k) r(k, 0, p)xi,1 (k),r(k, 'k, p)xi,' k, and r(k, 'k, p)xi,' k(k) are examples of r(k, 'k, p)xi,' k(k).(48), (49), (55), and (56). (59).linearized to the same degree method [46]. Consider the expression r(k, s, p)xi ,s(k). We havetodosomething.Introducer(k,s,,,,,,,,,,,,,,,,p)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(k)xi,s(= r(k, r(k, r(k, r(Auxiliary variable (s, p)xi ,s (k). From(42), we have 0 r(k, s, p) s(k), which, when combined with r(k, s, p) s(k), gives us xi, s(k) 0 1, 1 indicates that 0 (k, s, p, I r 0 (k, s, p, I r 0 (k, s, p, I r 0 (k, s, p, I r 0 (k, s, p, I r 0 (k,

B. Formulation Equivalence (NS-I) and Formulation Equivalence (NS-II) (NS-II)In this section, we'll demonstrate that, notwithstanding their variations, formulations (NS-I) and (NS-II) are identical. are derived in a multitude of ways and take on a variety of forms. There are numerous forms. The term "equivalence" refers to the notion that two things are equivalent. Both formulations mean the same thing. The system here is an optimal solution to the slicing problem. More For each possible formulation point (x, y, z, r, s, t, t, t, t, t, t, t, t,)By combining X, Y, Z, and R, we can create a credible solution (X, Y, Z, R). (NS-II). of formulation (NS-I), allowing the two to work together. The formulae are the same. at the appropriate locations, with the objective value being the same, and vice versa.

Theorem 1: (NS-I) and (NS-II) are equal.

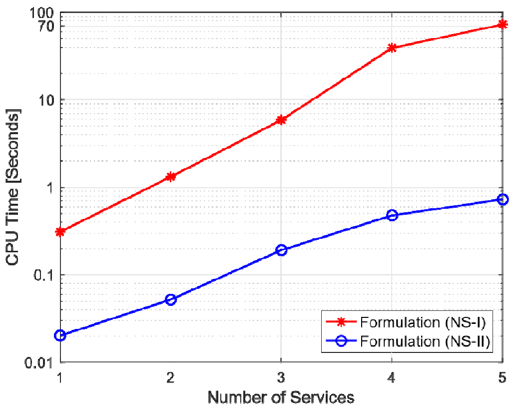
interchangeable. (X, Y, Z, R,) and (X, Y, Z, R,) will be used. In this proof, Z, R,) are used.The formulation has been relaxed to allow for more investigation in this area (NS-II). paper.

V. NUMERICAL RESULTS

In this section, we provide numerical results to compare.

The effectiveness of our suggested problem formulations(NS-I)(NS-II), in addition to the current issue [7] formulas (NS-II).[21]. We begin by doing.To see what happens, we'll run some numerical tests. compare and contrast in terms of computing efficiency of several formulations(In addition, NS-I.) (NS-II). After that, we'll show you some examples.the outcomes of thesimulationsubstantiate the effectiveness of theOver [21], and we presented a formulation (NS-II). Cutting-edge formulations. Finally, we evaluate our performance.Our suggested formulation (NS-II) functions well in a variety of situations.configurations of the network D(k) and are D(k) and are D(k) and are D(k) and are D(k) and are D(k) and are D(ka random selection

We create 100 problem scenarios at a time.For each fixed number of services in our system, at random results provided below are based on simulations.those outcomes

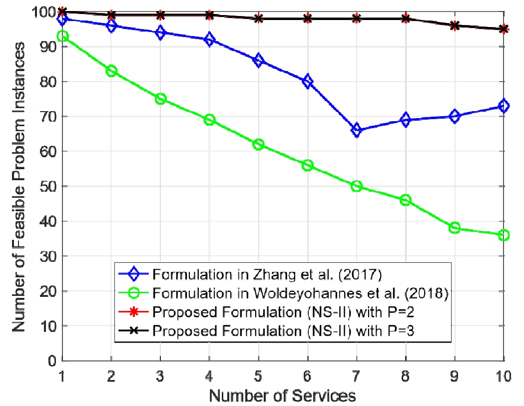


The CPU time required to solve formulations (NS-I) is shown in Figure 3. (NS-II).

The average amount of time it takes a computer to solve a problem (NS-I)Figure 1 shows the relationship between (NS-II) and the number of services.3.There's a lot more, as you can see in Fig. 3.The NS-II formulation is more efficient to solve than the NS-I.constructing (NS-I). When the quantity of services equals the number of people, especially from 1 to 5.The amount of CPU time required to solve the NS-I formulation is more than the amount of time required to tackle the problemThe time required to solve the (NS-II) is 70 seconds, however, the time required to solve the takes less than a second to formulate (NS-I). We can make a diagram.Based on the simulation results, the following conclusions can be drawn: The formulation (NS-II) outperforms the formulation by a significant margin. In terms of content,option. As a result, we shall only use and discuss formulation in the following (NS-II). [2] proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs). The group signature scheme is widely used in VANETs for secure communication, the existing systems based on group signature scheme provides verification delay in certificate revocation list checking

B. Actual Formulation vs. Proposed Formulation

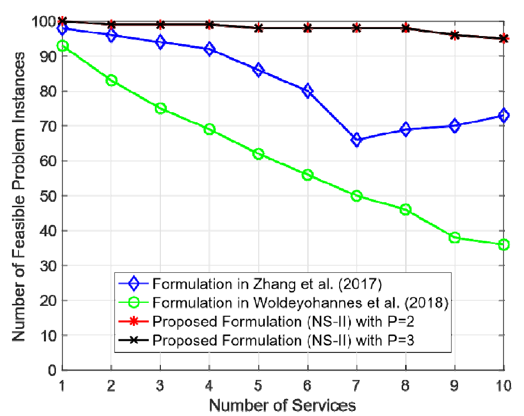
In this paragraph, we offer simulation data to demonstrate the efficacy of our proposed solution.in compared to the formulations in [21]. the topology of the fish network studied in [10] is considered.consideration. There are 112 nodes and 440 connections in this network.There are 86 nodes in this network that could be useful.There is only one node that can be chosen as the source node.be designated as the flow's origin. The currents' for further information on the destination node. SixService functions may be handled by cloud nodes:Five of them are assigned to two services at random.The last of f's functions, f 4, is chosen. every function of the service



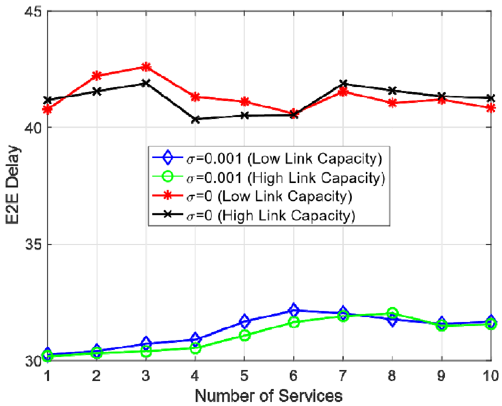
The number of problem cases that can be solved utilizing the formulations in [6, 21], as well as our proposed formulation, is shown in Figure 4. (NS-II).

The number of possible problem cases is depicted in Figure 4, [21], and our suggested model as a function of time. (NS-II) with P = 2 and P = 3, where P is the principal component. the maximum number of transportation routes that can be used given to any two cloud nodes that process two data streams functions that are closely related to a service type because it isn't stated explicitly , The diamond in blue The E2E delay is used to produce the curve in Fig. 4.taking constraints into consideration We figure out a way to solve the problem. Replace the result with the resulting solution to the limitations on E2Eenergy usage or service E2E delay). The efficiency of the solution is compromised. Then we compare the original to our problem formulation (NS-II).

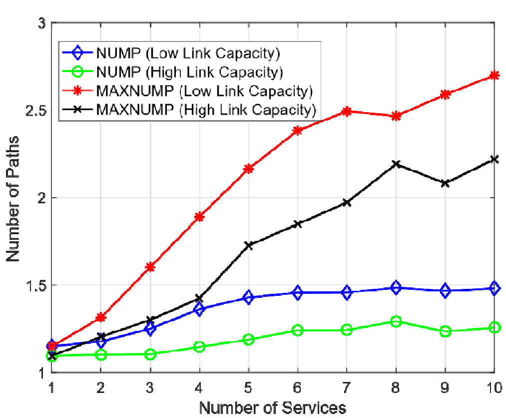
Formulations can be found in a variety of forms. To begin, as seen in Fig.4. There is a great deal of flexibility. Our suggestion for a formulation(NS-II) enables traffic routing. for coping with a much larger number of people's difficulties that can be handled using the formulation of [21](This can be thought of as a variation of our formula) (NS-I), or formulation (NS-II), as indicated, with P = 1Section III), particularly if the number is significant. The quantity number of services accessible is impressive. For instance, if the number

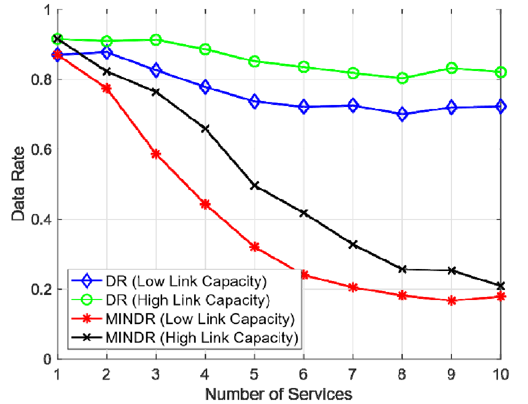


• The number of cloud nodes that have been turned on. Figure 5 depicts the average number of activated cloud nodes in the physical network. That is clear. as was expected, More cloud nodes to be activated for both More cloud nodes must be triggered as the game progresses



The number of services on offer is increasing. Furthermore, the number of activated cloud nodes in the two groups is virtually equal when the number of services is modest (e.g., |K| 6).equal. When the population grows, however, more services are necessary. The number of services is large (for example, |K| 7). Cloud nodes must be connected in the low-difficulty problem. Take part in activities. when contrasted to individuals that have a strong connection. capacity This can be explained in the following way. As the number of services grows, the number of users on the network grows, and so does the amount of traffic on the network. This leads to the situation where some cloud is triggered. Due to the nature of some services, nodes are unable to process their functions. because the capacity of some lines is insufficient to route the traffic flow of information As a result, more cloud nodes are required in general. [6] discussed because of various appealing focal points, agreeable correspondences have been broadly viewed as one of the promising systems to enhance throughput and scope execution in remote interchanges. [8] discussed that Helpful correspondence is developing as a standout amongst the most encouraging procedures in remote systems by reason of giving spatial differing qualities pick up. The transfer hub (RN) assumes a key part in agreeable correspondences, and RN choice may generously influence the execution pick up in a system with helpful media get to control (MAC).





the data rates on the associated pathways and the traffic from their source nodes to destination nodes4 Specifically, following We determine the minimum for each problem instance when we solve it. the number of paths [47] and the minimum data rate that corresponds to these routes, marked by the letters NUMP and DR, required realization. the traffic flow routing technique for each service ForLet MAXNUMP and MINDR stand for MAXNUMP and MINDR, respectively, for each problem case. the highest NUMP and lowest DR among all the associated services results of the average NUMP and the outcomes of the average NUMP are plotted in Figures 7 and 8.MAXIMUM, as well as average DR and MINDR, are used. In general, as the number of services grows, so does the number of NUMPs.MAXIMUM grows in size, indicating that there are more pathways. are used to maintain the flow of traffic the more traffic there is, or the smaller the link capacity, the more traffic routing flexibility is normally used and used in our proposed formulation (NS-II

VI. CONCLUSIONS AND NEXT STEPS

In this research, we looked at the network slicing problem, which is critical in 5G and B5G networks. For the network, we have proposed two novel MBLP formulations. common slicing problem that can be addressed optimallyGurobi, for example, is a problem solver. The formulations we propose reduce the weighted sum of the entire system's overall power usage cloud network (equal to the number of cloud instances that have been activated)nodes) and the overall latency of all SFCaffected services requirements, all services' E2E latency constraints, and capacity limits on all cloud nodes and linkages While we're here to demonstrate that the two formulations we've given are mathematically sound when compared to the first formulation, the second formulation is comparable. The first has a huge advantage.

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