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(54) **ENDPOINT SELECTION FOR PLACEMENT OF NETWORK SLICE(S) IN A 5G NETWORK**

(71) Applicant: **Cisco Technology, Inc.**, San Jose, CA (US)

(72) Inventors: **Arghya Mukherjee**, Acton, MA (US); **John J Mullooly**, Colts Neck, NJ (US); **Robert Crowe**, Apex, NC (US); **Waris Sagheer**, San Ramon, CA (US)

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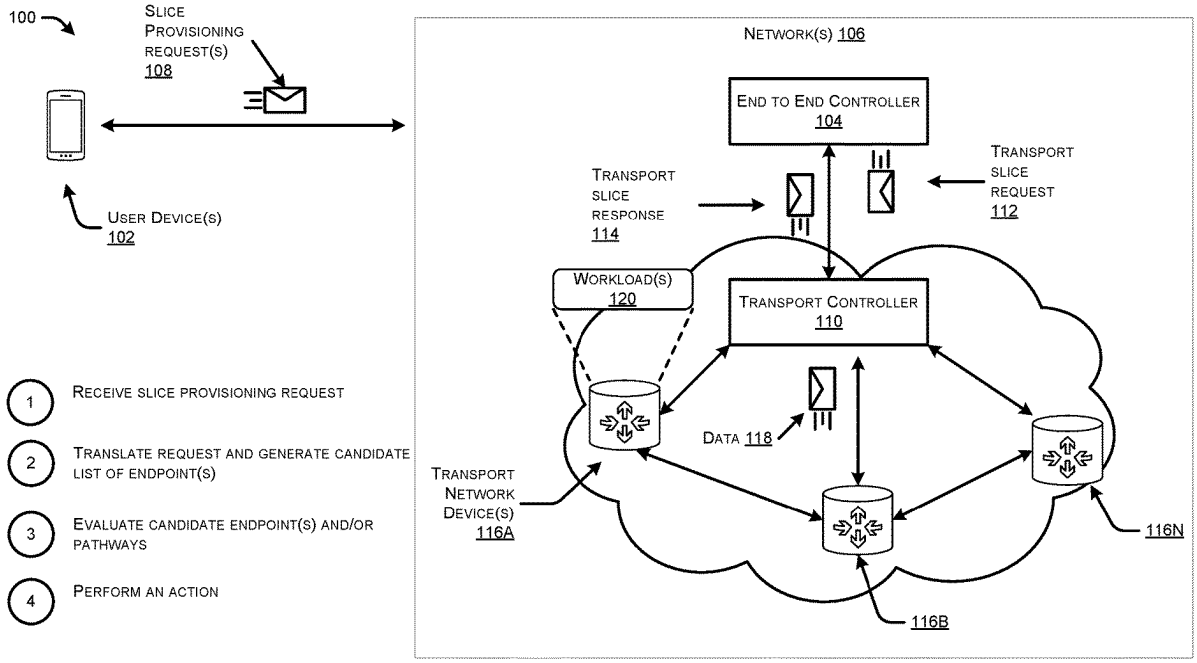
(57) **ABSTRACT**

This disclosure describes techniques and mechanisms for enabling an end-to-end controller of a network to offload decisions about placement of network slices to the transport controller. By doing so, the transport controller can intelligently determine optimal placement based on intent (e.g., external intent of the end-to-end controller and internal intent of the transport controller), internal transport network analytics functions, SLO/SLE constraints, real-time telemetry data, and more to provide dynamic and optimal placement of network slices. That is the described techniques dynamically utilize information from within the transport domain to define the placement of network slices. Thus, placements are more accurate, thereby reducing latency and improving functioning of the network, as well as providing an improved user experience by meeting SLO/SLE constraints.



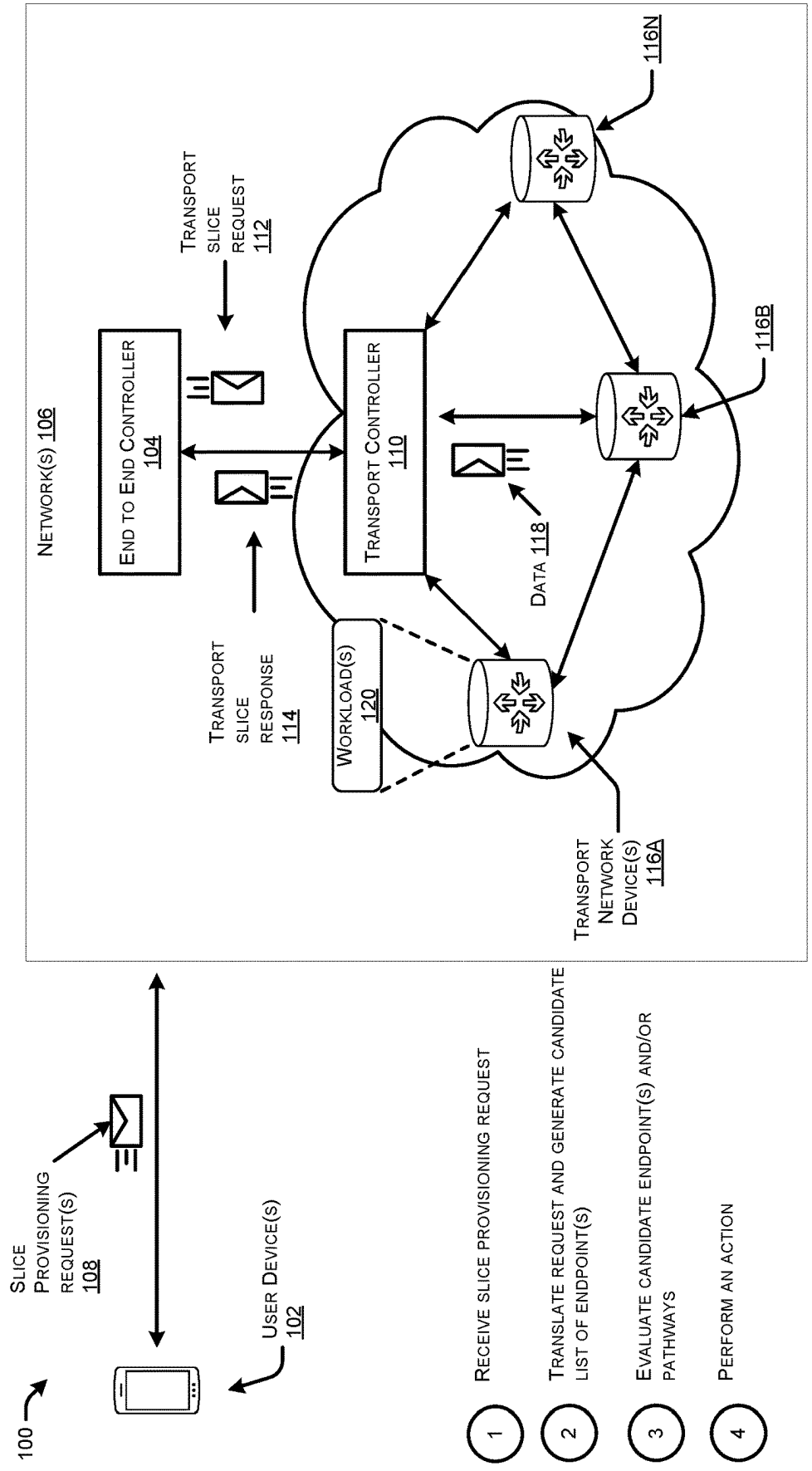

100
User Device(s) 102
Slice Provisioning Request(s) 108
Network(s) 106
End to End Controller 104
Transport Slice Request 112
Transport Slice Response 114
Transport Controller 110
Workload(s) 120
Data 118
Transport Network Device(s) 116A
116B
116N
1 Receive slice provisioning request
2 Translate request and generate candidate list of endpoint(s)
3 Evaluate candidate endpoint(s) and/or pathways
4 Perform an action

FIG. 1

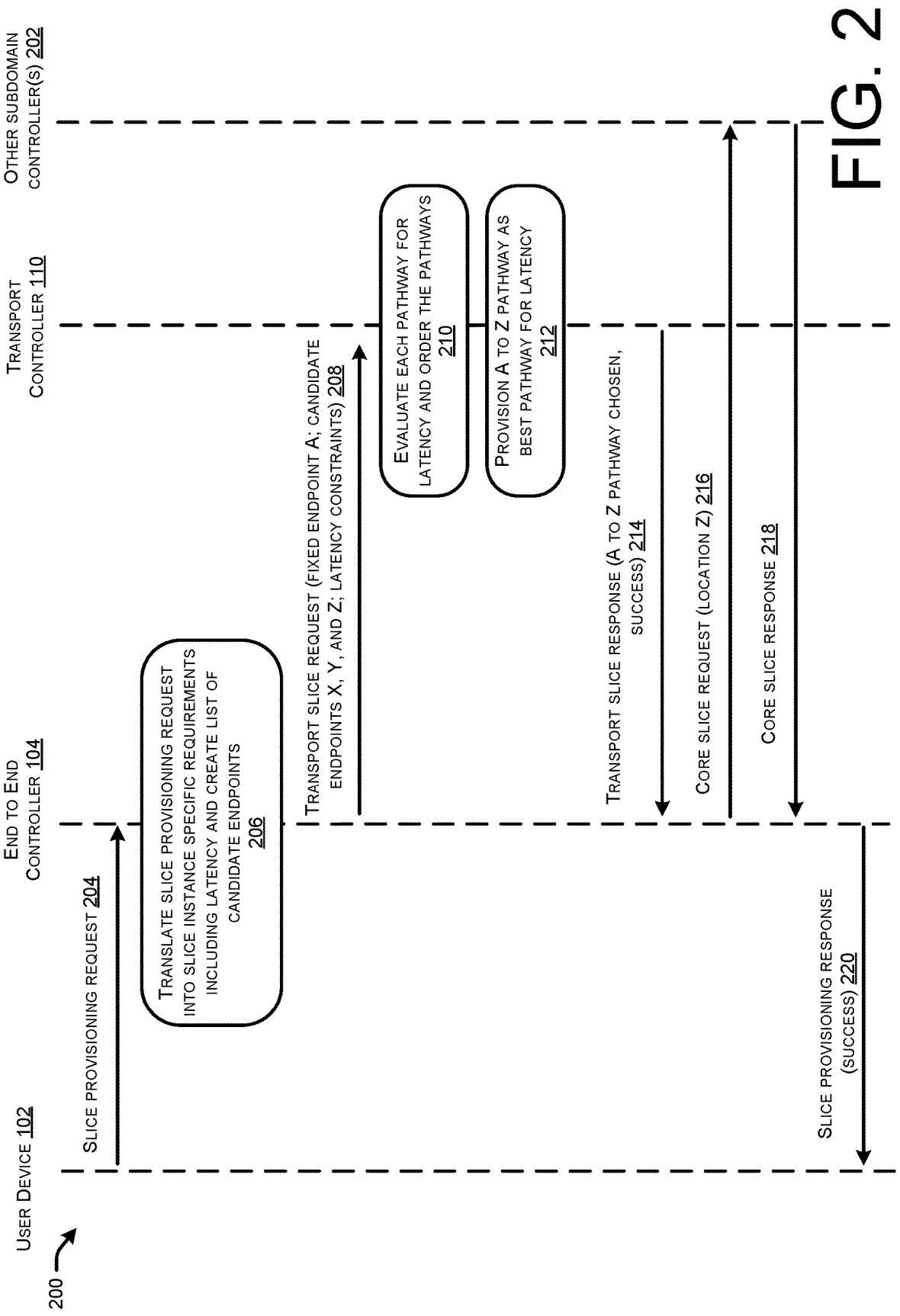

200
User Device 102
End to End Controller 104
Transport Controller 110
Other subdomain controller(s) 202
Slice provisioning request 204
Translate slice provisioning request into slice instance specific requirements including latency and create list of candidate endpoints 206
Transport slice request (fixed endpoint A; candidate endpoints X, Y, and Z; latency constraints) 208
Evaluate each pathway for latency and order the pathways 210
Provision A to Z pathway as best pathway for latency 212
Transport slice response (A to Z pathway chosen, success) 214
Core slice request (location Z) 216
Core slice response 218
Slice provisioning response (success) 220

FIG. 2

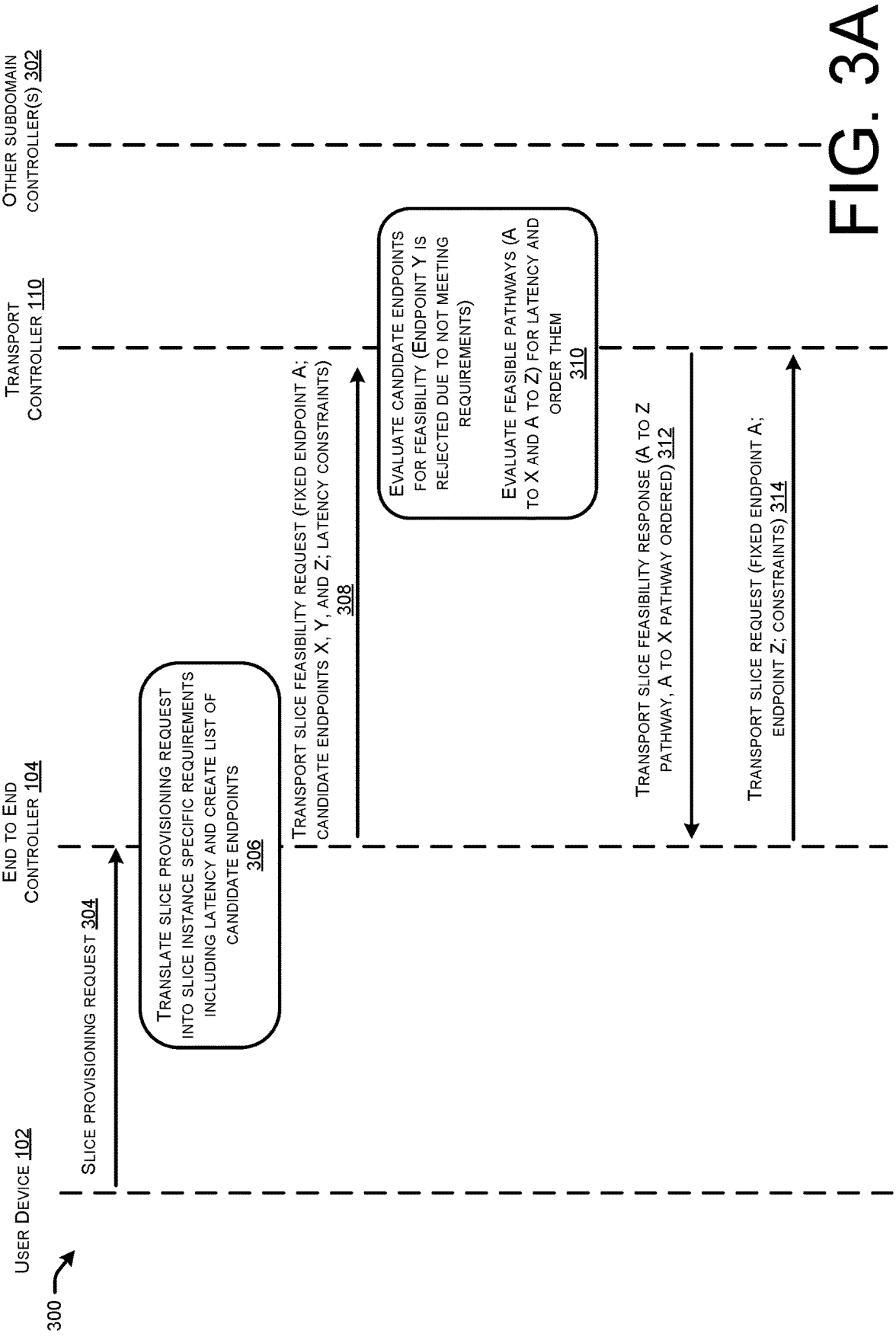

300
User Device 102
End to End Controller 104
Transport Controller 110
Other subdomain controller(s) 302
Slice provisioning request 304
Translate slice provisioning request into slice instance specific requirements including latency and create list of candidate endpoints 306
Transport slice feasibility request (fixed endpoint A; candidate endpoints X, Y, and Z; latency constraints) 308
Evaluate candidate endpoints for feasibility (Endpoint Y is rejected due to not meeting requirements)
Evaluate feasible pathways (A to X and A to Z) for latency and order them 310
Transport slice feasibility response (A to Z pathway, A to X pathway ordered) 312
Transport slice request (fixed endpoint A; endpoint Z; constraints) 314

FIG. 3A

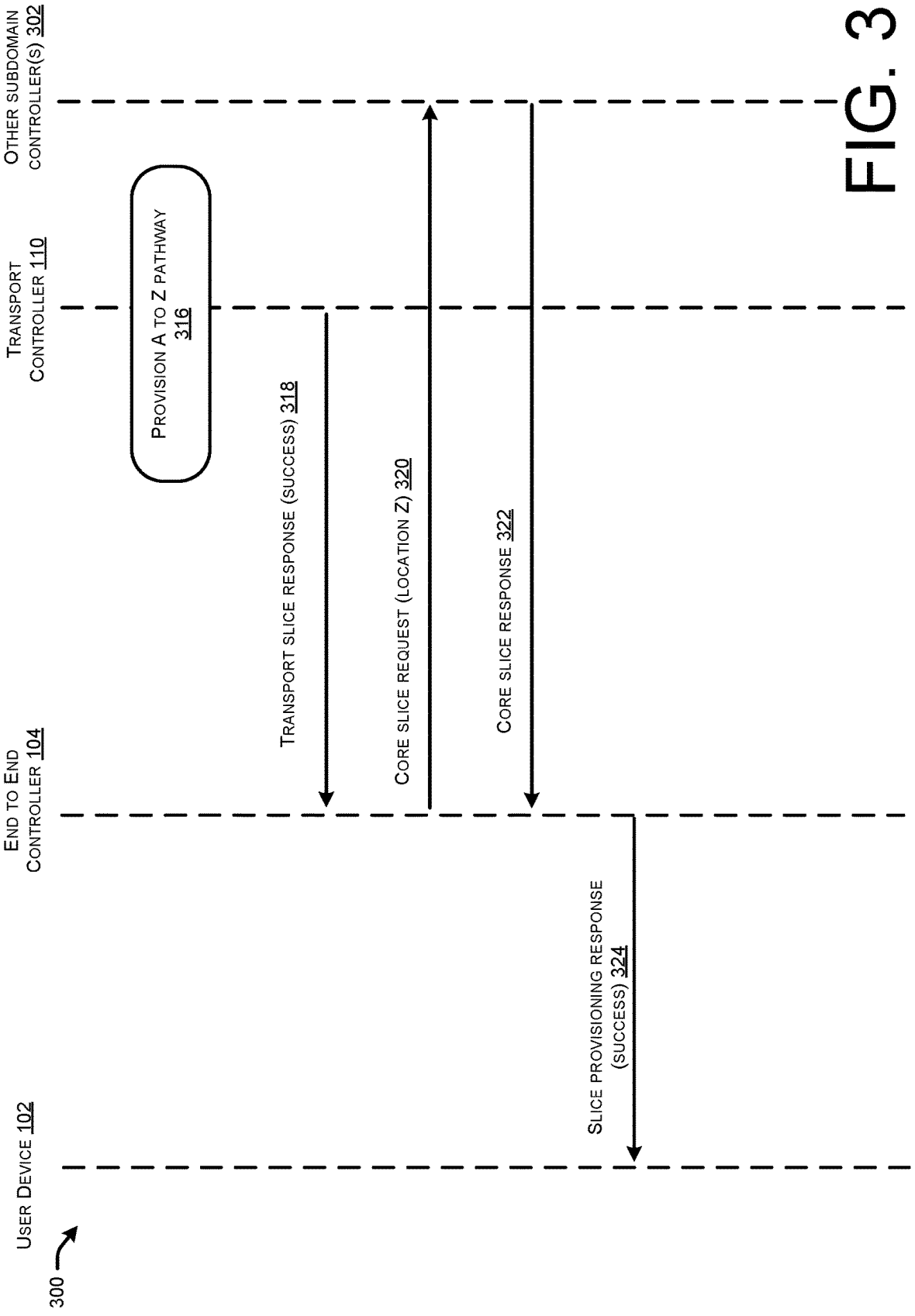

300
User Device 102
End to End Controller 104
Transport Controller 110
Other subdomain controller(s) 302
Provision A to Z pathway 316
Transport slice response (success) 318
Core slice request (location Z) 320
Core slice response 322
Slice provisioning response (success) 324

FIG. 3B

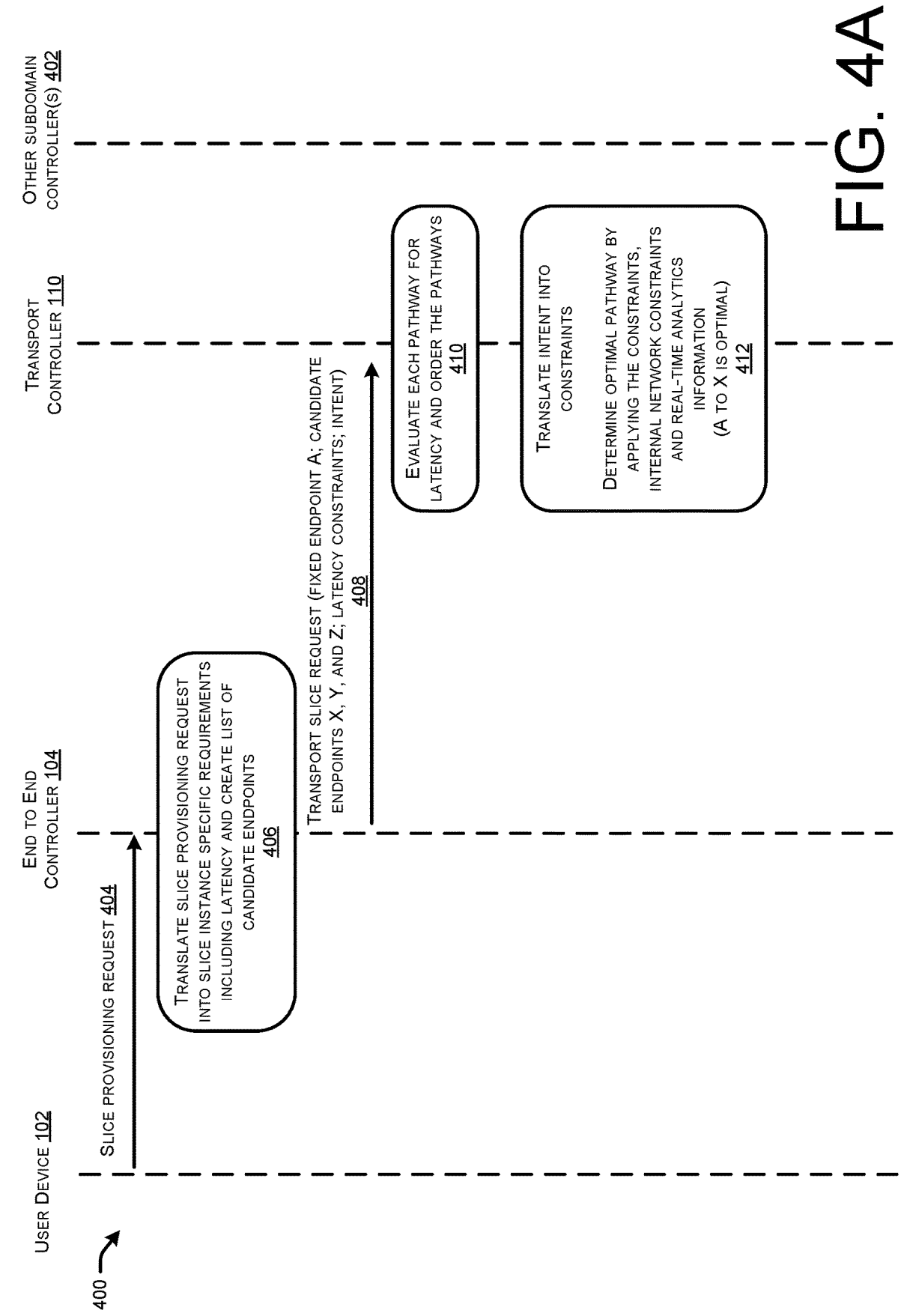

400
User Device 102
End to End Controller 104
Transport Controller 110
Other subdomain controller(s) 402
Slice provisioning request 404
Translate slice provisioning request into slice instance specific requirements including latency and create list of candidate endpoints 406
Transport slice request (fixed endpoint A; candidate endpoints X, Y, and Z; latency constraints; intent) 408
Evaluate each pathway for latency and order the pathways 410
Translate intent into constraints
Determine optimal pathway by applying the constraints, internal network constraints and real-time analytics information (A to X is optimal) 412

FIG. 4A

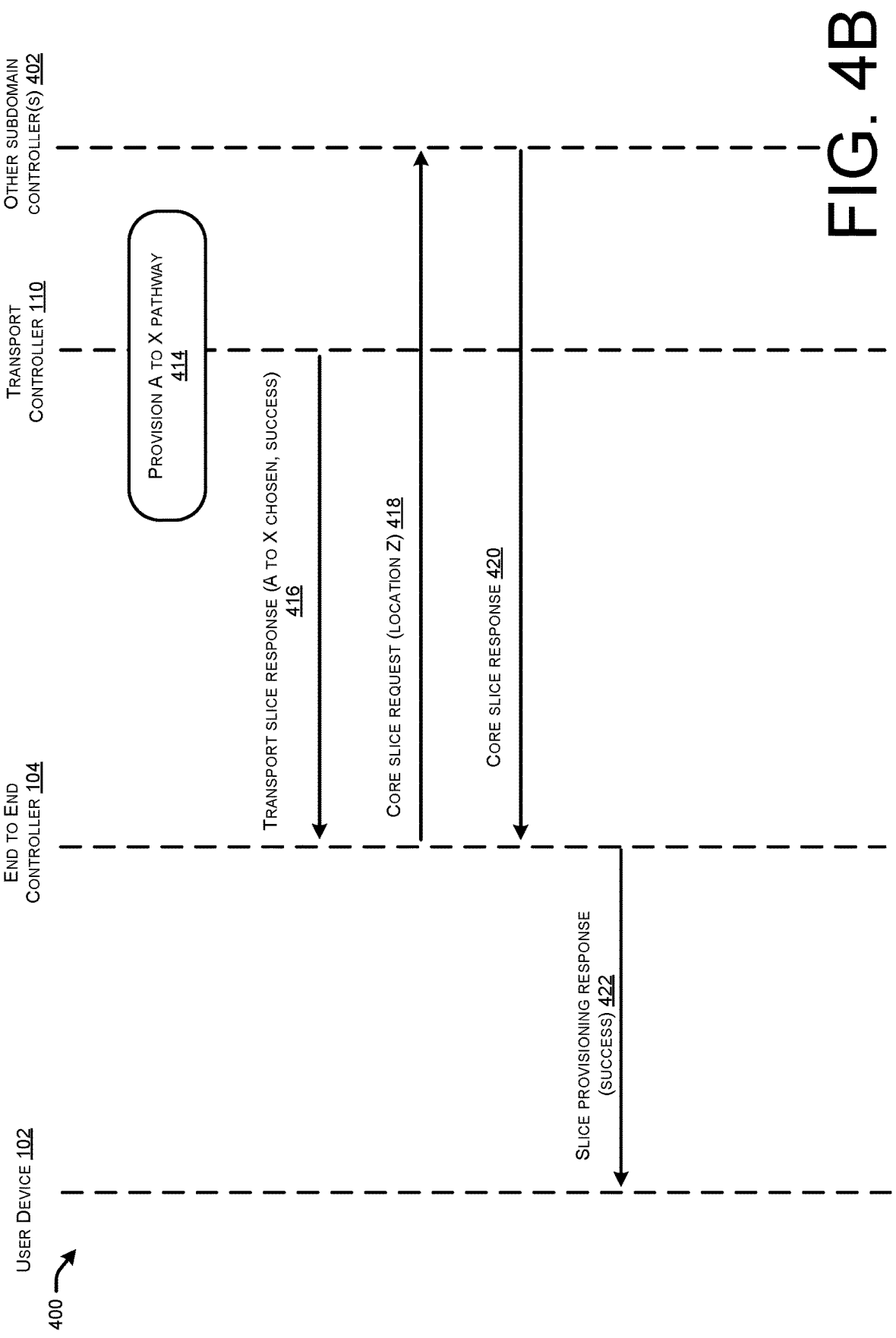

400
User Device 102
End to End Controller 104
Transport Controller 110
Other subdomain controller(s) 402
Provision A to X pathway 414
Transport slice response (A to X chosen, success) 416
Core slice request (location Z) 418
Core slice response 420
Slice provisioning response (success) 422

FIG. 4B

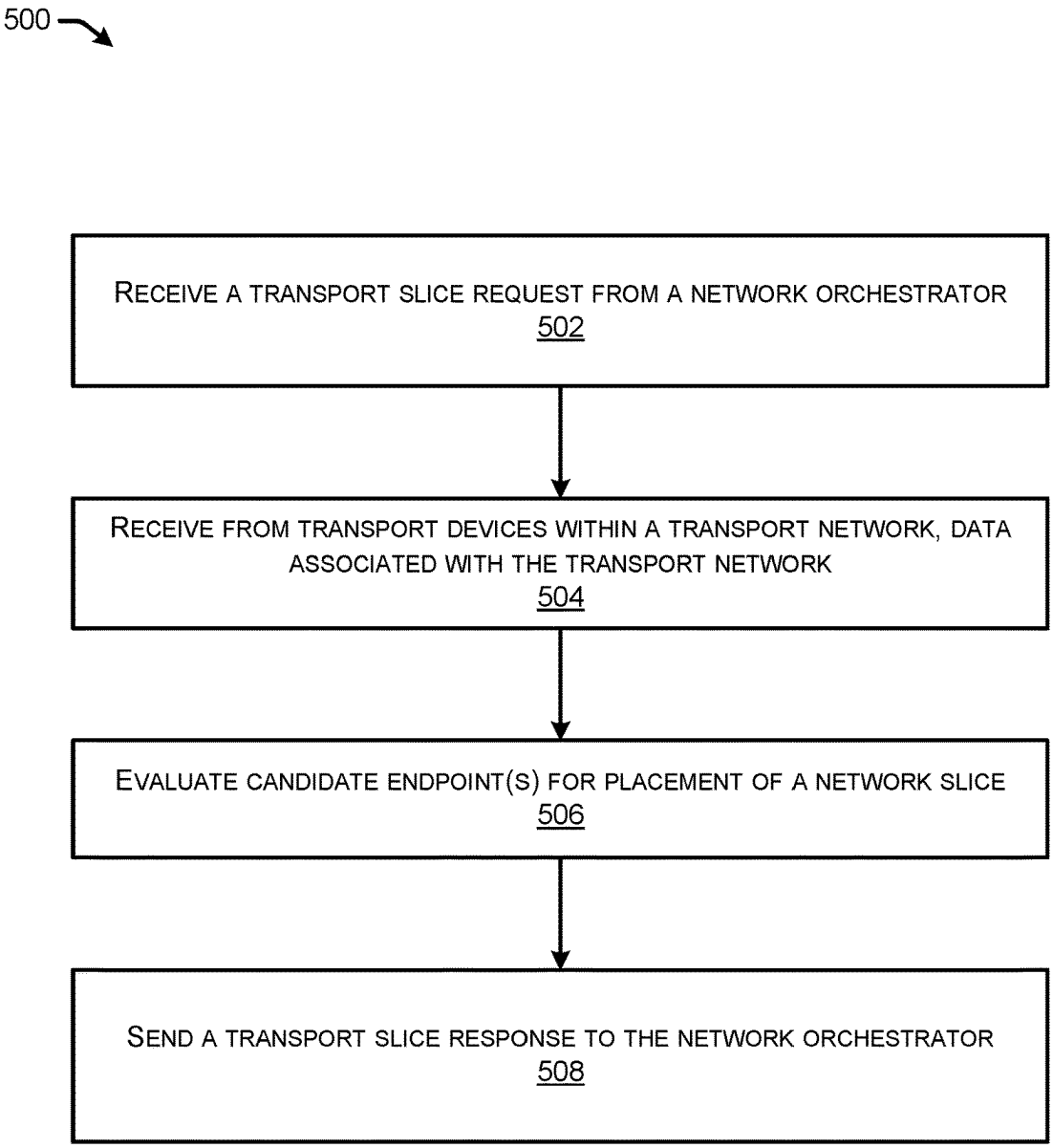

500
RECEIVE A TRANSPORT SLICE REQUEST FROM A NETWORK ORCHESTRATOR
502
RECEIVE FROM TRANSPORT DEVICES WITHIN A TRANSPORT NETWORK, DATA ASSOCIATED WITH THE TRANSPORT NETWORK
504
EVALUATE CANDIDATE ENDPOINT(S) FOR PLACEMENT OF A NETWORK SLICE
506
SEND A TRANSPORT SLICE RESPONSE TO THE NETWORK ORCHESTRATOR
508

FIG. 5

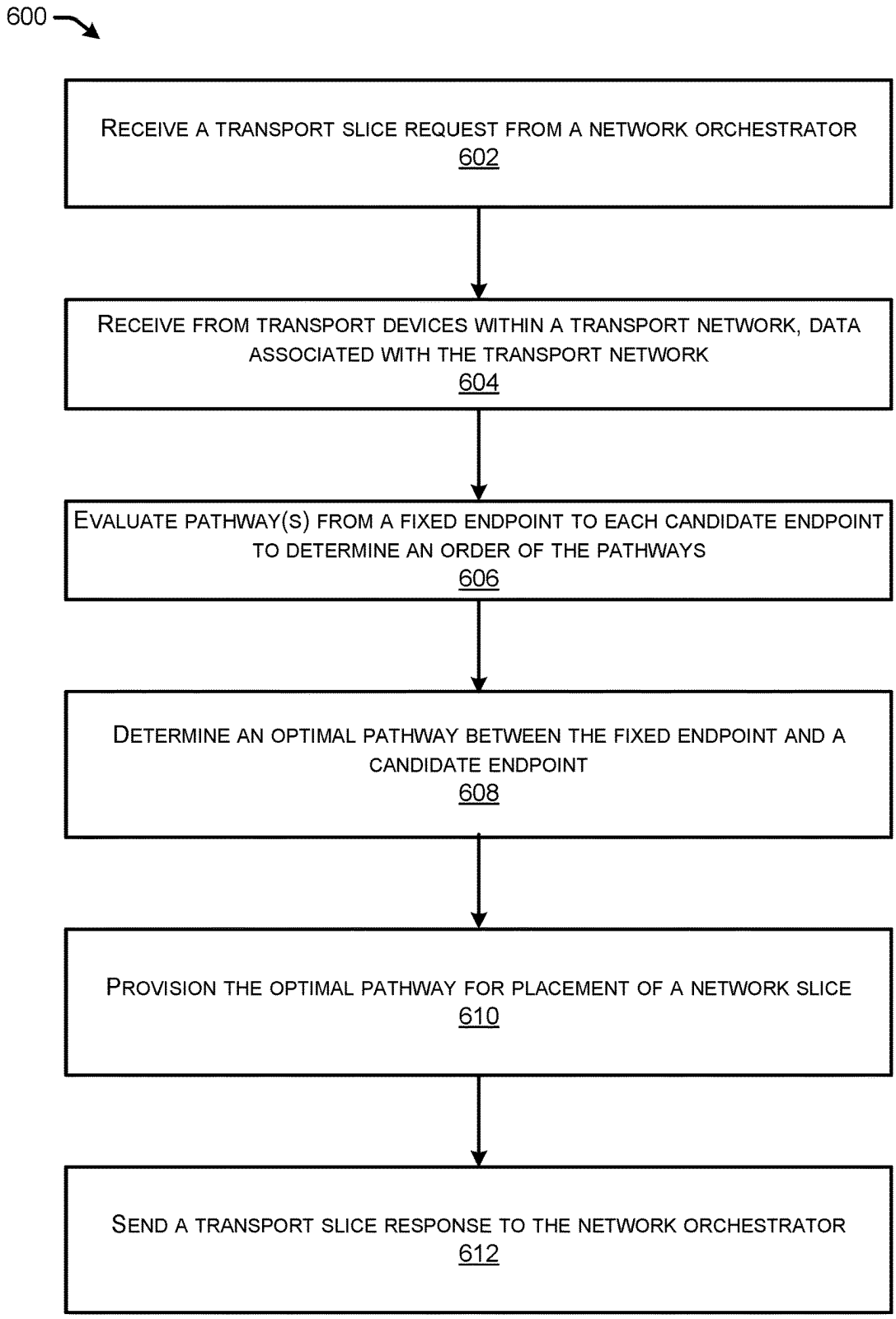

600
RECEIVE A TRANSPORT SLICE REQUEST FROM A NETWORK ORCHESTRATOR
602
RECEIVE FROM TRANSPORT DEVICES WITHIN A TRANSPORT NETWORK, DATA ASSOCIATED WITH THE TRANSPORT NETWORK
604
EVALUATE PATHWAY(S) FROM A FIXED ENDPOINT TO EACH CANDIDATE ENDPOINT TO DETERMINE AN ORDER OF THE PATHWAYS
606
DETERMINE AN OPTIMAL PATHWAY BETWEEN THE FIXED ENDPOINT AND A CANDIDATE ENDPOINT
608
PROVISION THE OPTIMAL PATHWAY FOR PLACEMENT OF A NETWORK SLICE
610
SEND A TRANSPORT SLICE RESPONSE TO THE NETWORK ORCHESTRATOR
612

FIG. 6

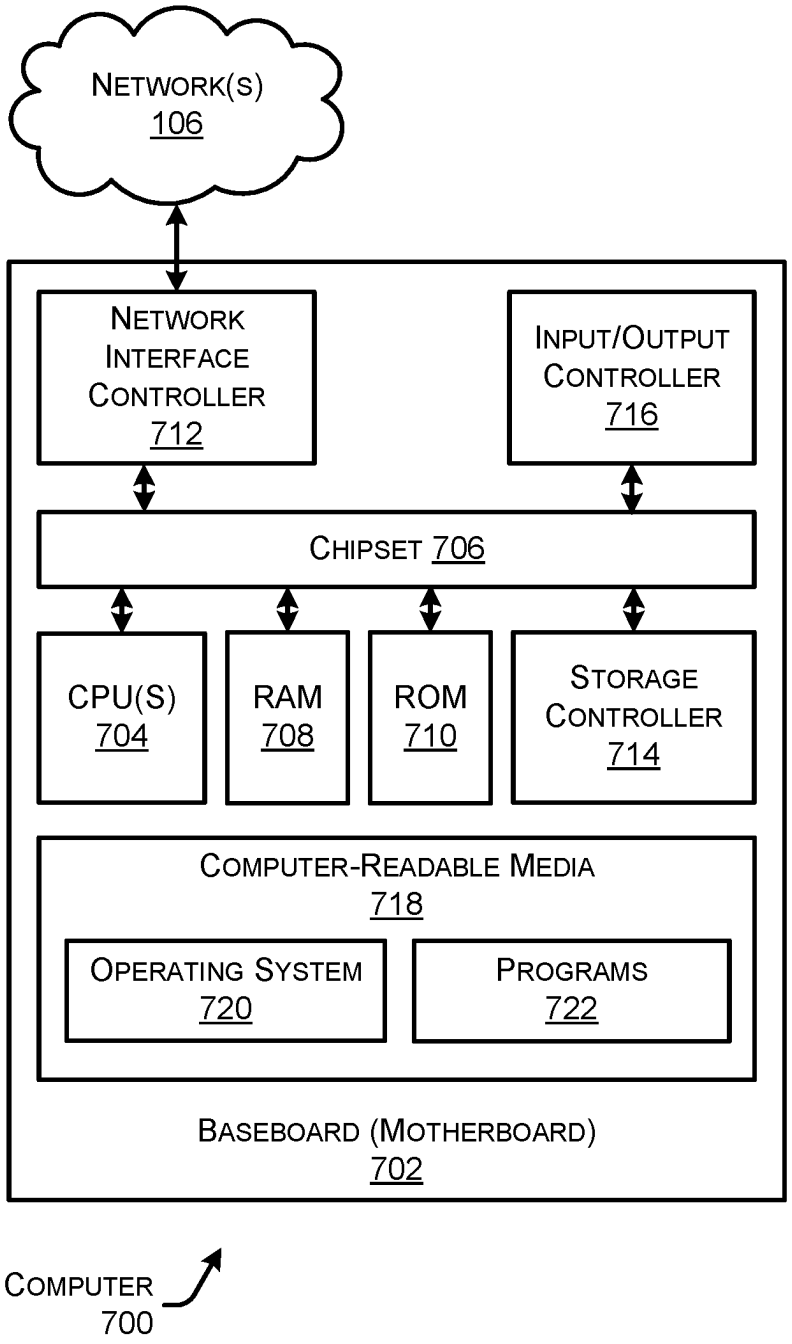

NETWORK(S)
106
NETWORK INTERFACE CONTROLLER
712
INPUT/OUTPUT CONTROLLER
716
CHIPSET 706
CPU(S)
704
RAM
708
ROM
710
STORAGE CONTROLLER
714
COMPUTER-READABLE MEDIA
718
OPERATING SYSTEM
720
PROGRAMS
722
BASEBOARD (MOTHERBOARD)
702
COMPUTER
700

FIG. 7

ENDPOINT SELECTION FOR PLACEMENT OF NETWORK SLICE(S) IN A 5G NETWORK

TECHNICAL FIELD

[0001] The present disclosure relates generally to the field of networking, and more particularly to techniques for dynamically selecting endpoints for network slices within a **5**G network.

BACKGROUND

[0002] Automation of network services is becoming more "intent based" to simplify the user experience and abstract the underlying complexities. One way of automating network services is by implementing "Network Slicing." Network slicing allows multiple logical networks to be created on top of a common shared physical network. Essentially this means segmenting parts of the network for different users and/or use cases. One example network that can be sliced is 5G networks. For example, 5G Network Slicing is becoming the recommended approach for both 5G mobile services and any generic transport service.

[0003] In a 5G network, a service providers may implement Network Slicing in order to dedicate portions of their network to meet their customers' specific needs. For example, in 5G networks, "Network Slicing," is where a user requests a specific service "intent" (or outcome) required to be provided by the network (i.e., Ultra-Reliable Low Latency (URLLC) or enhanced Mobile Broadband (eMBB) for high bandwidth services) with the expectation that the service provider can satisfy that intent. Additionally, the IETF has defined this "intent" as a set of Service Level Objectives (SLOs) (e.g., measurable constraints of delay, bandwidth, and loss), and Service Level Expectations (SLEs), (e.g., unmeasurable objectives such as "only transit encrypted links"). Along with the service intent, the user must select which endpoints (or Service Demarcation points (SDPs)) are required to be connected.

[0004] In 5G networks, these endpoints (SDPs) specify the transport network locations for the various components such as the User Plane Functions (UPFs) and the gNodeBs. The end-to-end controller of a 5G network uses the SDPs to dictate placement decisions for network slices that are assigned to the transport network, but this is unfortunately prior to determining if the transport network can even meet the service intent between the locations (e.g., datacenters, regions, etc.) of the SDPs. That is, the existing technology and IETF standards dictate that the endpoints are chosen by the end-to-end controller without consideration of whether the service intent can be met, and the decision is then sent to the network transport controller of the transport network for network path provisioning.

[0005] However, the selection of SDPs is a static decision that does not take into account real time topology information on which endpoints can best meet required SLO/SLE constraints. This results in endpoints being selected that may not meet required SLO/SLE constraints. Further, the selected endpoints may not represent the best or optimal pathway to meet the required constraints, resulting in less accurate placement of network slices.

[0006] Accordingly, there is a need to a more robust, accurate, and dynamic solution for slice endpoint selection and placement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The detailed description is set forth below with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items. The systems depicted in the accompanying figures are not to scale and components within the figures may be depicted not to scale with each other.

[0008] FIG. **1** illustrates a system-architecture diagrams of an environment in which dynamic endpoint selection based on transport conditions is supported.

[0009] FIG. **2** illustrates a flow diagram of example communications corresponding to enabling a transport controller to dynamically evaluate and select a pathway based on a constraint and without a dry run (e.g., feasibility indication of each of the candidate endpoints).

[0010] FIGS. **3**A and **3**B illustrate a flow diagram of example communications corresponding to enabling a transport controller to implement a dry run of potential endpoints for a network slice by evaluating feasibility of each candidate endpoint based on a constraint.

[0011] FIGS. **4**A and **4**B illustrate a flow diagram of example communications corresponding to enabling a transport controller to dynamically evaluate and select a pathway based on various constraints and intents.

[0012] FIG. **5** illustrates a flow diagram of an example method for a system to enable dynamic endpoint selection based on transport conditions.

[0013] FIG. **6** illustrates a flow diagram of an example method for a enabling a transport controller to dynamically evaluate and select a pathway based on various constraints and intents.

[0014] FIG. **7** is a computer architecture diagram showing an illustrative computer hardware architecture for implementing a server device that can be utilized to implement aspects of the various technologies presented herein.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

[0015] The present disclosure relates generally to techniques for dynamically selecting endpoints for network slices within a 5G network.

[0016] A method to perform techniques described herein, where the method may be implemented by a transport controller of a transport network. In some examples, the method includes receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints. In some examples, the method includes receiving, from transport devices within the transport network, data associated with the transport network. The method further includes evaluating, based at least in part on the data and the transport slice request, the one or more candidate endpoints for placement of the network slice. The method also includes sending, based at least in part on the evaluating, a transport slice response to the network orchestrator.

[0017] Another method to perform techniques described herein may be implemented by a transport controller of a transport network. The method may include receiving, from a network orchestrator, a transport slice request associated

with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, a constraint, and an intent. The method may include receiving, from transport devices within the transport network, data associated with the transport network. The method may include evaluating, based at least in part on the data and the transport slice request, pathways from the fixed endpoint to each candidate endpoint of the one or more candidate endpoints to determine an order of the pathways. The method may further include determining, based at least in part the intent and second data of the transport controller, an optimal pathway of the pathways between the fixed endpoint and a candidate endpoint. The method may also include provisioning, the optimal pathway from the fixed endpoint to the candidate endpoint for placement of the network slice. The method may include sending a transport slice response to the network orchestrator.

[0018] Additionally, the techniques described herein may be performed by a system and/or device having non-transitory computer-readable media storing computer-executable instructions that, when executed by one or more processors, performs the method described above.

EXAMPLE EMBODIMENTS

[0019] Automation of network services is becoming more "intent based" to simplify the user experience and abstract the underlying complexities. One way of automating network services is by implementing "Network Slicing." Network slicing allows multiple logical networks to be created on top of a common shared physical network. Essentially this means segmenting parts of the network for different users and/or use cases. One example network that can be sliced is 5G networks. For example, 5G Network Slicing is becoming the recommended approach for both 5G mobile services and any generic transport service.

[0020] In a 5G network, a service providers may implement Network Slicing in order to dedicate portions of their network to meet their customers' specific needs. For example, in 5G networks, "Network Slicing," is where a user requests a specific service "intent" (or outcome) required to be provided by the network (i.e., Ultra-Reliable Low Latency (URLLC) or enhanced Mobile Broadband (eMBB) for high bandwidth services) with the expectation that the service provider can satisfy that intent. Additionally, the IETF has defined this "intent" as a set of Service Level Objectives (SLOs) (e.g., measurable constraints of delay, bandwidth, and loss), and Service Level Expectations (SLEs), (e.g., unmeasurable objectives such as "only transit encrypted links"). Along with the service intent, the user must select which endpoints (or Service Demarcation points (SDPs)) are required to be connected.

[0021] In 5G networks, these endpoints (SDPs) specify the transport network locations for the various components such as the User Plane Functions (UPFs) and gNodeBs. The end-to-end controller of a 5G network uses the SDPs to dictate placement decisions for network slices that are assigned to the transport network, but this is done prior to determining if the transport network can even meet the service intent between the locations (e.g., datacenters, regions, etc.) of the SDPs. That is, the existing technology and IETF standards dictate that the endpoints are chosen by the end-to-end controller without consideration of whether the service intent can be met, and the decision is then sent to the network transport controller of the transport network for network path provisioning.

[0022] However, the selection of SDPs is a static decision that does not take into account real time topology information on which endpoints can best meet required SLO/SLE constraints. This results in endpoints being selected that may not meet required SLO/SLE constraints. Further, the selected endpoints may not represent the best or optimal pathway to meet the required constraints, resulting in less accurate placement of network slices.

[0023] Accordingly, there is a need to a more robust, accurate, and dynamic solution for slice endpoint selection and placement.

[0024] This disclosure describes techniques and mechanisms for utilizing a transport controller to provide a critical mapping from intent to the best actual transport network characteristics when selecting and placing network slices. For instance, the techniques may be implemented by a transport controller of a transport network. In some examples, the techniques include receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints. In some examples, the techniques include receiving, from transport devices within the transport network, data associated with the transport network. The techniques further include evaluating, based at least in part on the data and the transport slice request, the one or more candidate endpoints for placement of the network slice. The techniques also include sending, based at least in part on the evaluating, a transport slice response to the network orchestrator.

[0025] Another method to perform techniques described herein may be implemented by a transport controller of a transport network. The techniques may include receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, a constraint, and an intent. The techniques may include receiving, from transport devices within the transport network, data associated with the transport network. The techniques may include evaluating, based at least in part on the data and the transport slice request, pathways from the fixed endpoint to each candidate endpoint of the one or more candidate endpoints to determine an order of the pathways. The techniques may further include determining, based at least in part the intent and second data of the transport controller, an optimal pathway of the pathways between the fixed endpoint and a candidate endpoint. The techniques may also include provisioning, the optimal pathway from the fixed endpoint to the best fit candidate endpoint for placement of the network slice. The techniques may include sending a transport slice response to the network orchestrator.

[0026] In some examples, the network orchestrator comprises an end-to-end controller within a network (e.g., such as a 5G network) that has visibility into all network layers. In some examples, the network slice may correspond to a location for a UPF. In some examples, the fixed endpoint may correspond to a location where the gNodeB is placed. In some examples, an endpoint (e.g., candidate endpoint or fixed endpoint) may comprise an SDP. In some examples, a candidate endpoint may correspond to a location where one or more UPFs are placed. In some examples, an endpoint

may correspond to a datacenter. In some examples, the one or more constraints may comprise one or more SLO/SLE constraints, such as latency, bandwidth or more advanced policies. In some examples, the transport network is included as part of a 5G network. In some examples, the endpoints may correspond to one or more transport devices within a non-5G transport network. In some examples, the transport devices may correspond to one or more site(s), server(s), and/or datacenters.

[0027] In some examples, the data from the transport devices may comprise real-time telemetry data (e.g., CPU data, number of surfaces a transport device has, how loaded the transport device is, traffic volume, etc.). In some examples, the data comprises historical information associated with a transport device, analytic data, an existing slice placement, and reservation data.

[0028] In some examples, the network orchestrator may receive a slice provisioning request. The network orchestrator may translate the slice provisioning request into slice instance specific constraints (e.g., such as latency). In some examples, the network orchestrator may generate a list of candidate endpoints. For instance, the network orchestrator may access a database of the network to determine which sites (e.g., endpoints) have the capacity to bring up portion (s) or all of the network slice. As an example, the candidate list may comprise a fixed endpoint (e.g., such as endpoint A) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the list may further comprise one or more constraints that need to be met for a particular user (such as latency), intent, etc. In some examples, the network orchestrator may send the list as part of a transport slice request to the transport controller of the transport network. In some examples, the list can be sent as part of a transport slice feasibility request. In this way, the network orchestrator may offload the decision of where to place a network slice to the transport controller, such that the decision is no longer static.

[0029] In some examples, such as where the transport controller receives the list as part of a transport slice request, the transport controller can evaluate each of the candidate endpoints and each pathway between the fixed endpoint to dynamically select and provision the optimal pathway. For instance, the transport controller may utilize telemetry data included in the data from the transport devices to evaluate whether each pathway can meet the constraint(s) in real-time. The transport controller may order the pathways based on best fit for meeting the constraint(s). In some examples, the transport controller may select and provision the pathway determined to be the best (e.g., optimal) fit for the constraints. In this way, the transport controller intelligently provisions a pathway for a network slice and sends the network orchestrator a response indicating the dynamic endpoint and pathway selected.

[0030] In some examples, such as where the transport controller receives the list as part of a transport slice feasibility request, the transport controller may evaluate candidate endpoint(s) to determine feasibility of each of the candidate endpoints. For instance, the transport controller may utilize the data to evaluate feasibility that the constraint (s) can be met by each of the candidate endpoints. The transport controller may order the candidate endpoints determined to be feasible based on best fit for meeting the constraint(s). In some examples, the transport controller may exclude one or more endpoints determined to not be feasible (e.g., not able to meet constraint(s)).

[0031] In some examples, the transport controller can utilize intent to evaluate each candidate endpoint and/or each pathway. For instance, the transport controller may utilize telemetry data, analytic data, and other data to evaluate whether each pathway can meet the constraint(s) in real-time. The transport controller may order the pathways based on best fit for meeting the constraint(s). The transport controller may consider intent when determining an optimal pathway. For instance, the transport controller may consider intent (e.g., intent of what the service associated with the slice provisioning request is for (e.g., streaming, etc.), intent of the network orchestrator (e.g., SLO/SLE constraints), and/or internal system information (e.g., tunnel affinity, availability of backup pathways, telemetry data, etc.) when determining an optimal pathway. In some examples, the transport controller may select and provision the pathway determined to be the best (e.g., optimal) fit based on the constraints and the intent. In this way, the transport controller intelligently provisions a pathway for a network slice and sends the network orchestrator a response indicating the dynamic endpoint and pathway selected.

[0032] In some examples, one or more machine learned models may be used to evaluate the one or more candidate endpoint(s) and/or the pathways. In some examples, the machine learning models may correspond to the IETF YANG model, that has been extended and augmented to provide candidate endpoints. In some examples, candidate endpoint(s), real-time telemetry data, and/or other information (e.g., analytic information, external intent, internal intent, historical information, etc.) may be input into the machine learning model and an ordered set of candidate endpoint(s) and/or pathway(s) may be output. In some examples, the machine learning models may be included as part of the end-to-end controller and/or the transport controller. In some examples, the end-to-end controller may utilize the machine learned models to generate a list of candidate endpoints.

[0033] Machine learning techniques include, but are not limited to supervised learning algorithms (e.g., artificial neural networks, Bayesian statistics, support vector machines, decision trees, classifiers, k-nearest neighbor, etc.), unsupervised learning algorithms (e.g., artificial neural networks, association rule learning, hierarchical clustering, cluster analysis, etc.), semi-supervised learning algorithms, deep learning algorithms, etc.), statistical models, etc. As used herein, the terms "machine learning," "machine-trained," and their equivalents, may refer to a computing model that can be optimized to accurately recreate certain outputs based on certain inputs. In some examples, the machine learning models include deep learning models, such as convolutional neural networks (CNN), deep learning neural networks (DNN), and/or artificial intelligence models. The term "neural network," and its equivalents, may refer to a model with multiple hidden layers, wherein the model receives an input (e.g., a vector) and transforms the input by performing operations via the hidden layers. An individual hidden layer may include multiple "neurons," each of which may be disconnected from other neurons in the layer. An individual neuron within a particular layer may be connected to multiple (e.g., all) of the neurons in the previous layer. A neural network may further include at least one fully-connected layer that receives a feature map output

by the hidden layers and transforms the feature map into the output of the neural network. In some examples, the neural network comprises a graph where each node of the graph represents a layer within the neural network. Each node may be connected as part of a chain (e.g., a concatenation of layers). In some examples, input may be received by a node within the graph, the input is computed by the node and gets passed to one or more additional nodes in the chain.

[0034] As noted above, prior to the techniques described herein, an end-to-end controller would receive a slice provisioning request with a constraint that an SLO of network delay to be less than 5 ms between a fixed endpoint (e.g., such as location A) and datacenter X (e.g., representing pathway A to X). The end-to-end controller would either (1) accept the slice provisioning request (e.g., a service will be provisioned), or (2) deny the slice provisioning request (e.g., based on determining there are no resources available to meet the SLO). Further, in existing technologies, many controllers simply do not have the intelligence to deny the slice provisioning request based on an SLO metric. In many cases, the service associated with the slice provisioning request may still be accepted and provisioned along with necessary Key Performance Indicators (KPIs), such as "less than a 5 ms delay", and then any available service assurance systems trigger an alarm that the KPIs have been exceeded.

[0035] In contrast to existing technologies, the techniques described herein may receive a slice service request for a specific SLO of network delay to be less than 5 ms between the fixed endpoint (e.g., location A) and "candidate" endpoint(s) of datacenter X, Y, and Z. Using the techniques described herein, the network transport controller may evaluate which of the three proposed destination endpoints (X, Y, or Z) is best to satisfy the request. Further, depending on the controller algorithm, if all three can satisfy the request, the transport controller may either randomly pick one of the candidate endpoints, round-robin across multiple requests to pick the next candidate endpoint on the list, pick a preferred candidate endpoint (i.e., "X", assuming this is a preferred order from the user), and/or use some other criteria to pick the best candidate endpoint and network path that best suits the service provider while still maintaining the user's SLO. Thus, the techniques described herein enable the transport controller, which has the best understanding of the real-time network conditions and existing slice reservations, to determine, out of the pool of candidate endpoints, which endpoint will best satisfy the requirement for the new slice being requested.

[0036] In this way, the techniques described herein enable an end-to-end controller to offload decisions about placement of network slices to the transport controller. By doing so, the transport controller can intelligently determine optimal placement based on intent (e.g., external intent of the end-to-end controller and internal intent of the transport controller), internal transport network analytics functions, SLO/SLE constraints, and real-time telemetry data, thereby providing dynamic and optimal placement of network slices. That is the described techniques dynamically utilize information from within the transport domain to define the placement of network slices (e.g., such as in the 5GC or RAN domains). Thus, placements are more accurate, thereby reducing latency and improving functioning of the network, as well as providing an improved user experience by meeting SLO/SLE constraints.

[0037] While the examples described focus on an embodiment related to a 5G network, it should be noted that the techniques described herein may apply to any network and/or service that provides transport services and supports an application across transport networks.

[0038] Certain implementations and embodiments of the disclosure will now be described more fully below with reference to the accompanying figures, in which various aspects are shown. However, the various aspects may be implemented in many different forms and should not be construed as limited to the implementations set forth herein. The disclosure encompasses variations of the embodiments, as described herein. Like numbers refer to like elements throughout.

[0039] FIG. **1** illustrates a system-architecture diagrams of an environment **100** in which dynamic endpoint selection based on transport conditions is supported. The user device(s) **102** may include one or more device(s), and may comprise any computing device, such as a mobile device, a laptop, a computer, a tablet, any Wi-Fi enabled device, any cellular enabled device, and/or any Bluetooth enabled device. In some examples, the user device **102** may correspond to a device of an administrator (not shown). The user device **102** may include one or more application(s) (not shown).

[0040] In some examples, the user device **102** may communicate with one or more of an end-to-end controller **104** via network(s) **106**. Network(s) **106** may include any combination of Personal Area Networks (PANs), Local Area Networks (LANs), Campus Area Networks (CANs), Metropolitan Area Networks (MANs), extranets, intranets, the Internet, Wide Area Networks (WANs)—both centralized and/or distributed—and/or any combination, permutation, and/or aggregation thereof. In some examples, the network(s) **106** may correspond to a private enterprise network, a cellular network (e.g., such as a 5g network), or any other type of network. The user device(s) **102** may communicate using any type of protocol over the network(s) **106**, such as the transmission control protocol/Internet protocol (TCP/IP) that is used to govern connects to and over the Internet.

[0041] In some examples, the end-to-end controller **104** is configured to receive a slice provisioning request **108** from the user device **102**. In some examples, the end-to-end controller **104** may comprise a computing device, processor(s), memory, etc. In some examples, the end-to-end controller **104** may correspond to a network orchestrator of the network **106**. For instance, the end-to-end controller **104** may correspond to a NSMF of a 5G network.

[0042] In some examples, the end-to-end controller **104** is configured to communicate with one or more subdomains within the network **106**. For instance, as illustrated in FIG. **1**, the end-to-end controller **104** may communicate with a transport controller **110** of a transport network. For instance, the end-to-end controller **104** may send transport slice request(s) **112** to the transport controller **110**. In some examples, the transport slice request(s) **112** may comprise a list. In some examples, the list may comprise a fixed endpoint (e.g., such as endpoint A) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the fixed endpoint A may correspond to a first transport network device **116**A and the one or more candidate endpoint(s) may correspond to one or more additional transport network device(s) **116**B, **116**N, etc. In some examples, the list may further comprise one or more con-

straints that need to be met for a particular user (such as latency), intent, etc. In some examples, the transport slice request **112** may correspond to a transport slice feasibility request.

[0043] In some examples, the transport controller **110** is configured to send transport slice response(s) **114** to the end-to-end controller **104**. In some examples, the transport slice response **114** may correspond to a transport slice feasibility response. In some examples, the transport slice feasibility response may indicate an ordered list of one or more feasible candidate endpoints. In some examples, the transport slice response **114** indicates a provisioned pathway and/or endpoint and an indication of a connection to the provisioned endpoint (e.g., connection successful, etc.).

[0044] In some examples, the transport controller **110** is configured to communicate with transport network device(s) **116** within the transport network. For instance, the transport controller **110** may receive data **118** from the transport network device(s) **116**. In some examples, the data may comprise real-time telemetry data. In some examples, the data from the transport devices may comprise real-time telemetry data (e.g., CPU data, number of surfaces a transport device has, how loaded the transport device is, traffic volume, etc.). In some examples, the data comprises historical information associated with a transport device, analytic data, an existing slice placement, and reservation data. In some examples, the transport devices may correspond to one or more site(s), server(s), and/or datacenters. In some examples, the transport network device(s) **116**A are configured to communicate with one or more other transport network device(s) **116**B, **116**N, etc. In some examples, the transport network device(s) **116** are configured to execute one or more workload(s) **120**. For instance, the workload(s) **120** may correspond to a network slice (e.g., such as a gNodeBs, UPFs, etc.).

[0045] In some examples, the transport controller **110** is configured to place network slice(s) at one or more endpoints. For instance, the transport controller **110** may provision network slice(s) automatically and dynamically and/or based on receiving instructions from the end-to-end controller **104**, where the instructions indicate an endpoint to place workload **120** (e.g., such as a network slice, gNodeB, UPFs, etc.) at. In some examples, the fixed endpoint may correspond to a location where the gNodeB is placed. In some examples, an endpoint (e.g., candidate endpoint or fixed endpoint) may comprise an SDP. In some examples, a candidate endpoint may correspond to a location where one or more UPFs are placed. As noted above, the endpoints (e.g., candidate endpoint(s) and/or fixed endpoint(s)) may correspond to one or more of the transport network device(s) **116**.

[0046] In some examples, an endpoint may correspond to a datacenter. In some examples, the one or more constraints may comprise one or more SLO/SLE constraints, such as latency. In some examples, the transport network is included as part of a 5G network. In some examples, the endpoints may correspond to one or more transport devices within the transport network. In some examples, the endpoints may correspond to one or more data centers. The one or more data centers may be physical facilities or buildings located across geographic areas that designated to store networked devices that are part of a manufacturer. The data centers may include various network devices, as well as redundant or backup components and infrastructure for power supply, data communications connections, environmental controls, and various security devices. In some examples, the data centers may include one or more virtual data centers which are a pool or collection of cloud infrastructure resources specifically designed for enterprise needs, and/or for cloud-based service provider needs. Generally, the data centers (physical and/or virtual) may provide basic resources such as processor (CPU), memory (RAM), storage (disk), and networking (bandwidth). However, in some examples the devices in the packet-forwarding networks may not be located in explicitly defined data centers, but may be located in other locations or buildings. In some examples, the endpoints may correspond to one or more network devices. In some examples, the network devices may correspond to any computing device, routers, switches, computers, or any other type of network device.

[0047] At "1", the end-to-end controller may receive a slice provisioning request **108** from a user device. For instance, the end-to-end controller **104** may receive the slice provisioning request **108** from user device **102**.

[0048] At "2", the end-to-end controller **104** may translate the request and generate a candidate list of endpoint(s). For instance, the end-to-end controller **104** may translate the slice provisioning request into slice instance specific constraints (e.g., such as latency). In some examples, the end-to-end controller **104** may generate a list of candidate endpoints. For instance, the end-to-end controller **104** may access a database of the network **106** to determine which sites (e.g., endpoints) have the capacity to bring up portion (s) or all of the network slice. As an example, the candidate list may comprise a fixed endpoint (e.g., such as endpoint A) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the list may further comprise one or more constraints that need to be met for a particular user (such as latency), intent, etc. In some examples, the end-to-end controller **104** may send the list as part of a transport slice request **112** to the transport controller **110** of the transport network. In some examples, the list can be sent as part of a transport slice feasibility request. In this way, the end-to-end controller **104** may offload the decision of where to place a network slice to the transport controller **110**.

[0049] At "3", the transport controller **110** may evaluate the candidate endpoint(s) and/or pathway(s). For instance, the transport controller **110** may evaluate each of the candidate endpoint(s) for feasibility. In some examples, the transport controller **110** may evaluate each of the pathways based on constraints indicated by the transport slice request. In some examples, the transport controller **110** may apply one evaluate each of the pathways based on different intent (s), internal system information, etc. In some examples, the transport controller **110** may utilize one or more machine learning model(s) to evaluate the candidate endpoint(s) and/or pathway(s).

[0050] At "4", the transport controller **110** may perform an action. For instance, the transport controller **110** may send the end-to-end controller **104** an ordered list of feasible candidate endpoint(s). In some examples, the transport controller **110** may select and provision an optimal pathway and send the end-to-end controller a transport slice response **114** indicating the selected endpoint and successful connection.

[0051] In this way, the transport controller **110** can either (1) provision a network slice and send a message back to the end-to-end controller **104** indicated the dynamic endpoint

used; or (2) hand-back a "dry-run" (feasibility indication) of the result (e.g., without provisioning a candidate endpoint) of suitable dynamic endpoints, such that the end-to-end controller **104** may decide to commit the change or not, given the endpoints selected.

[0052] FIG. **2** illustrates a flow diagram **200** of example communications corresponding to enabling a transport controller to dynamically evaluate and select a pathway based on a constraint and without a dry run (e.g., feasibility indication of each of the candidate endpoints). In the illustrated example, the constraint corresponds to latency, however any other suitable constraint may be used. Additionally, the illustrated example in FIG. **2** may correspond to an implementation of the described techniques that modify and extend the IETF-based YANG models to allow an end-to-end controller to request and receive a network slice with a list of candidate endpoints. That is FIG. **2** illustrates an example implementation that augments the IETF-based YANG model with a candidate SDP option. In some examples, the extension/augmentation of the IETF-based YANG model is optional, such that the standard behavior of the model may still work.

[0053] As illustrated, the system may include a user device **102** as described above. In some examples, the user device **102** corresponds to a customer facing controller (e.g., such as a user portal for accessing service(s) of the network **106**). The system may include the end-to-end controller **104** and transport controller **110** described above. The system may also include other subdomain controller(s) **202**. For instance, the other subdomain controller(s) **202** may correspond to other subdomain(s) and/or layers of the network **106**. As an example, the other subdomain controller(s) **202** illustrated in FIG. **2** may correspond to a core network slice management function (C-NSSMF) of a 5G network.

[0054] As illustrated, at **204**, the end-to-end controller **104** may receive a slice provisioning request **204** from the user device **102**. For instance, the slice provisioning request **204** may be received from a customer facing controller of the user device **102**. In some examples, the slice provisioning request **204** may be associated with a user of the user device **102** accessing a service of a service provider and/or the network **106**. As noted above, the slice provisioning request **204** may comprise a service "intent" (or outcome) required to be provided by the network (i.e., Ultra-Reliable Low Latency (URLLC) or enhanced Mobile Broadband (eMBB) for high bandwidth services) with the expectation that the service provider can satisfy that intent. As noted above, the service intent may comprise one or more SLOs (e.g., measurable constraints of delay, bandwidth, and loss) and/or SLEs, (e.g., unmeasurable objectives such as "only transit encrypted links"). In some examples, the slice provisioning request may comprise an indication of one or more endpoints (or Service Demarcation points (SDPs)) to be connected.

[0055] At **206**, the end-to-end controller **104** may translate the slice provisioning request into one or more slice instance specific requirements (e.g., constraint(s), including latency). In some examples, the end-to-end controller **104** generates a list of candidate endpoints. For example, the end-to-end controller **104** may access a database of the network **106** to determine which sites (e.g., endpoints) have the capacity to bring up portion(s) or all of the network slice and/or at least one of the slice instance specific constraint(s). As an example, the endpoints may comprise a fixed endpoint (e.g., such as endpoint A) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the list may further comprise one or more constraints that need to be met for a particular user (such as latency), intent, etc. As noted above, the one or more constraint(s) may be designated by a user of the user device **102**, such that the end-to-end controller **104** may identify and include one or more latency constraint(s) or other constraint(s) that need to be met.

[0056] At **208**, the end-to-end controller **104** may send a transport slice request to the transport controller **110**. The transport slice request **208** may comprise the list. As noted above the list may include a fixed endpoint (e.g., endpoint A) and one or more candidate endpoint(s) (e.g., candidate endpoint X, candidate endpoint Y, and candidate endpoint Z). The list may further comprise latency constraints that the end-to-end controller **104** needs to meet.

[0057] At **210**, the transport controller **110** may evaluate each of the pathways for latency and may order the pathways. For instance, the transport controller **110** may receive data from one or more transport devices within the transport network. The data may comprise real-time telemetry data. The transport controller **110** may evaluate, using the telemetry data and/or one or more machine learning models, each of the pathways to determine whether each pathway can meet the latency constraint(s) included in the transport slice request. The transport controller **110** may then order the pathways based on which pathway best meets the latency constraint(s). As an example, the latency constraint(s) may indicate that latency for a pathway needs to be less than 20 ms. The transport controller **110** may determine, based on the real-time telemetry data, that pathways A to X (e.g., from fixed endpoint A to candidate endpoint X), A to Y (e.g., from fixed endpoint A to candidate endpoint Y), and A to Z (e.g., from fixed endpoint A to candidate endpoint Z) each have a latency that is less than 20 ms. The transport controller **110** may then order the pathways based on determining which pathway has the lowest latency time. For instance, pathway A to Z may have the lowest latency time when compared to pathways A to X and A to Y. Accordingly, pathway A to Z may be identified as the best pathway based on the latency constraints.

[0058] At **212**, the transport controller **110** may provision the A to Z pathway as the best pathway for latency. As noted above, based on identifying the A to Z pathway as having the lowest latency time of the pathways and meeting the latency constraint(s), the transport controller **110** may dynamically and automatically provision the A to Z pathway for the network slice. For instance, the transport controller **110** may decide the best place for the UPF is at endpoint Z and may make the connection between the fixed endpoint A and endpoint Z available and then communicate these results to the end-to-end controller such that the UPF can be deployed at that location.

[0059] At **214**, the transport controller **110** may send a transport slice response to the end-to-end controller **104**. In some examples, the transport slice response **214** may comprise an indication of the provisioned pathway (e.g., "A to Z pathway chosen") and a connection status of the pathway (e.g., "success").

[0060] At **216**, the end-to-end controller **104** may send a core slice request to the other subdomain controller(s) **202**.

The core slice request **216** may indicate an endpoint (e.g., "location Z"). In some examples, location Z may correspond to endpoint Z.

[0061] At **218**, the end-to-end controller **104** may receive a core slice response from the other subdomain controller(s) **202**.

[0062] At **220**, the end-to-end controller **104** may send a slice provisioning response to the user device **102**. For instance, the slice provisioning response may be sent to the customer facing controller of the user device **102**. In some examples, the slice provisioning response may comprise a status associated with whether the slice provisioning request **204** was completed. For example, the slice provisioning response **220** may indicate that the network slice was successfully provisioned.

[0063] Accordingly, the end-to-end controller may generate a transport slice request that comprises multiple candidate endpoints and then offloads the decision process to an intelligent network transport controller. In this way, the transport controller is better positioned to dynamically and automatically make a placement decision regarding the network slice, using data that is unavailable to the end-to-end orchestrator. Thus, the transport controller may utilize real-time network telemetry data (e.g., (high CPUs, how many surfaces it has, how loaded it is, how much traffic is going through it, etc.) from all transport devices in the pathway, historical information, and other analytic data, along with existing slice placement and reservation information, to dynamically select and provision the best endpoint (or set of endpoints) out of the candidate endpoints, which can then meet the desired SLO/SLE intent.

[0064] FIGS. **3**A and **3**B illustrate a flow diagram **300** of example communications corresponding to enabling a transport controller to implement a dry run of potential endpoints for a network slice by evaluating feasibility of each candidate endpoint based on a constraint. In the illustrated example, the constraint corresponds to latency, however any other suitable constraint may be used. In some examples, the communications correspond to an embodiment that enable the transport controller to determine an ordered list of feasible candidate endpoints based on current conditions of the transport network.

[0065] As illustrated, the system may include a user device **102** as described above. In some examples, the user device **102** corresponds to a customer facing controller (e.g., such as a user portal for accessing service(s) of the network **106**). The system may include the end-to-end controller **104** and transport controller **110** described above. The system may also include other subdomain controller(s) **302**. For instance, the other subdomain controller(s) **302** may correspond to other subdomain(s) and/or layers of the network **106**. As an example, the other subdomain controller(s) **302** illustrated in FIGS. **3**A and **3**B may correspond to a core network slice management function (C-NSSMF) of a 5G network.

[0066] As illustrated in FIG. **3**A, at **304**, the end-to-end controller **104** may receive a slice provisioning request **204** from the user device **102**. For instance, the slice provisioning request **204** may be received from a customer facing controller of the user device **102**. In some examples, the slice provisioning request **304** may be associated with a user of the user device **102** accessing a service of a service provider and/or the network **106**. As noted above, the slice provisioning request **304** may comprise a service "intent" (or outcome) required to be provided by the network (i.e., Ultra-Reliable Low Latency (URLLC) or enhanced Mobile Broadband (eMBB) for high bandwidth services) with the expectation that the service provider can satisfy that intent. As noted above, the service intent may comprise one or more SLOs (e.g., measurable constraints of delay, bandwidth, and loss) and/or SLEs, (e.g., unmeasurable objectives such as "only transit encrypted links"). In some examples, the slice provisioning request may comprise an indication of one or more endpoints (or Service Demarcation points (SDPs)) to be connected.

[0067] At **306**, the end-to-end controller **104** may translate the slice provisioning request into one or more slice instance specific requirements (e.g., constraint(s), including latency). In some examples, the end-to-end controller **104** generates a list of candidate endpoints. For example, the end-to-end controller **104** may access a database of the network **106** to determine which sites (e.g., endpoints) have the capacity to bring up portion(s) or all of the network slice and/or at least one of the slice instance specific constraint(s). As an example, the endpoints may comprise a fixed endpoint (e.g., such as endpoint A) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the list may further comprise one or more constraints that need to be met for a particular user (such as latency), intent, etc. As noted above, the one or more constraint(s) may be designated by a user of the user device **102**, such that the end-to-end controller **104** may identify and include one or more latency constraint(s) or other constraint(s) that need to be met.

[0068] At **308**, the end-to-end controller **104** may send a transport slice feasibility request to the transport controller **110**. The transport slice feasibility request **308** may comprise the list. As noted above the list may include a fixed endpoint (e.g., endpoint A) and one or more candidate endpoint(s) (e.g., candidate endpoint X, candidate endpoint Y, and candidate endpoint Z). The list may further comprise latency constraints that the end-to-end controller **104** needs to meet. In some examples, the transport slice feasibility request **308** may comprise instructions to perform a dry run (e.g., evaluate feasibility of different candidate endpoint(s) and/or pathway(s)) given current conditions of the transport network.

[0069] At **310**, the transport controller **110** may evaluate each of the candidate endpoints for feasibility. For instance, each candidate endpoint may be evaluated to determine whether latency condition(s) may be met. As illustrated in FIG. **3**A, candidate endpoint Y is rejected due to not meeting requirements (e.g., latency condition(s)) indicated by the transport slice feasibility request. In some examples, the transport controller **110** may only evaluate the candidate endpoints for feasibility. That is, the transport controller **110** may not create pathways between the fixed endpoint A and each of the candidate endpoint(s). In this example, the transport controller **110** may order the feasible candidate endpoints based on best fit for the latency condition(s). In some examples, the transport controller **110** may additionally or alternatively evaluate feasibility of pathways between the fixed endpoint A and the feasible candidate endpoints (e.g., endpoint X and endpoint Z).

[0070] As noted above, the transport controller **110** may receive data from one or more transport devices within the transport network. The data may comprise real-time telemetry data. The transport controller **110** may evaluate, using the telemetry data and/or one or more machine learning

models, each of the candidate endpoint(s) and/or pathways to determine whether they can meet the latency constraint(s) included in the transport slice feasibility request.

[0071] At **312**, the transport controller **110** may send a transport slice feasibility response to the end-to-end controller **104**. In some examples, the transport slice feasibility response **312** may comprise an ordered list of the feasible candidate endpoint(s) and/or the feasible pathway(s). As illustrated in FIG. **3**A, the ordered list may indicate that feasible pathway A to Z is the best fit based on the latency conditions, and that feasible pathway A to X is also permissible (e.g., A to X also meets the latency conditions). As noted above, the transport slice feasibility response **312** may exclude candidate endpoint Y, based on the determination that candidate endpoint Y does not meet the latency constraints.

[0072] At **314**, the end-to-end controller **104** may send a transport slice request to the transport controller **110**. The transport slice request **314** may comprise an indication of the fixed endpoint and at least one of the candidate endpoints, along with one or more constraints. The transport slice request **314** may comprise instructions to provision the pathway from fixed endpoint A to selected endpoint Z. For instance, the end-to-end controller **104** may select the feasible A to Z pathway based on the determination that it is the best fit for latency constraints. The end-to-end controller **104** may select the feasible A to Z pathway (or a feasible candidate endpoint) based on other considerations as well, such as end-to-end information available to the end-to-end controller (e.g., optimization information, workload management information, etc.).

[0073] As illustrated in FIG. **3**B, at **316**, the transport controller **110** may provision the A to Z pathway in response to the instructions included in the transport slice request. For instance, the transport controller **110** may setup the connection such that a UPF can be placed at endpoint Z and may make the connection between the fixed endpoint A and endpoint Z available.

[0074] At **318**, the transport controller **110** may send a transport slice response to the end-to-end controller **104**. In some examples, the transport slice response **318** may comprise an indication of a connection status of the provisioned pathway (e.g., "success").

[0075] At **320**, the end-to-end controller **104** may send a core slice request to the other subdomain controller(s) **302**. The core slice request **320** may indicate an endpoint (e.g., "location Z"). In some examples, location Z may correspond to endpoint Z. In some examples, the core slice request may correspond to a second network slice. The second network slice may be different from the network slice associated with the network slice feasibility request **308**. In some examples, the second network slice may correspond to a second portion of the network slice associated with the slice provisioning request **304**.

[0076] At **322**, the end-to-end controller **104** may receive a core slice response from the other subdomain controller(s) **302**.

[0077] At **324**, the end-to-end controller **104** may send a slice provisioning response to the user device **102**. For instance, the slice provisioning response may be sent to the customer facing controller of the user device **102**. In some examples, the slice provisioning response **324** may comprise a status associated with whether the slice provisioning request **304** was completed. For example, the slice provisioning response **324** may indicate that the network slice was successfully provisioned.

[0078] Accordingly, the transport controller may intelligently determine feasibility of candidate endpoint(s) based on current transport network conditions, such that the end-to-end controller may be better informed when selecting an endpoint and/or pathway. Thus, the transport controller may hand-back a "dry-run" (feasibility indication) of the result (e.g., without provisioning a candidate endpoint) of suitable dynamic endpoints, such that the end-to-end controller **104** may decide to commit the change or not, given the endpoints selected or recommended.

[0079] FIGS. **4**A and **4**B illustrate a flow diagram **400** of example communications corresponding to enabling a transport controller to dynamically evaluate and select a pathway based on various constraints and intents. For instance, FIGS. **4**A and **4**B correspond to an example embodiment where the transport controller may consider constraint(s) (e.g., latency and/or other SLO/SLE constraint(s)), external intent of the end-to-end controller (affinities, least number of hops, what the service is for, etc.), telemetry data, as well as internal network constraints/information (e.g., transport network state, how loaded router(s) are, tunnel affinity, availability of backup pathways when dynamically selecting and provisioning an optimal pathway for a network slice.

[0080] As illustrated, the system may include a user device **102** as described above. In some examples, the user device **102** corresponds to a customer facing controller (e.g., such as a user portal for accessing service(s) of the network **106**). The system may include the end-to-end controller **104** and transport controller **110** described above. The system may also include other subdomain controller(s) **402**. For instance, the other subdomain controller(s) **402** may correspond to other subdomain(s) and/or layers of the network **106**. As an example, the other subdomain controller(s) **402** illustrated in FIGS. **4**A and **4**B may correspond to a core network slice management function (C-NSSMF) of a 5G network.

[0081] As illustrated in FIG. **4**A, at **404**, the end-to-end controller **104** may receive a slice provisioning request from the user device **102**. For instance, the slice provisioning request **204** may be received from a customer facing controller of the user device **102**. In some examples, the slice provisioning request **404** may be associated with a user of the user device **102** accessing a service of a service provider and/or the network **106**. As noted above, the slice provisioning request **404** may comprise a service "intent" (or outcome) required to be provided by the network (i.e., Ultra-Reliable Low Latency (URLLC) or enhanced Mobile Broadband (eMBB) for high bandwidth services) with the expectation that the service provider can satisfy that intent. As noted above, the service intent may comprise one or more SLOs (e.g., measurable constraints of delay, bandwidth, and loss) and/or SLEs, (e.g., unmeasurable objectives such as "only transit encrypted links"). In some examples, the slice provisioning request may comprise an indication of one or more endpoints (or Service Demarcation points (SDPs)) to be connected.

[0082] At **406**, the end-to-end controller **104** may translate the slice provisioning request into one or more slice instance specific requirements (e.g., constraint(s), such as SLO/SLE constraints, including latency). In some examples, the end-to-end controller **104** generates a list of candidate endpoints. For example, the end-to-end controller **104** may access a

database of the network **106** to determine which sites (e.g., endpoints) have the capacity to bring up portion(s) or all of the network slice and/or at least one of the slice instance specific constraint(s). As an example, the endpoints may comprise a fixed endpoint (e.g., such as endpoint A, where a gNodeB is located) and one or more candidate endpoints (e.g., endpoint X, endpoint Y, and endpoint Z). In some examples, the list may further comprise one or more constraints that need to be met for a particular user (such as latency), intent (e.g., external intent of the end-to-end controller **104**, intent of what the service is for, etc.), etc. As noted above, the one or more constraint(s) may be designated by a user of the user device **102**, such that the end-to-end controller **104** may identify and include one or more latency constraint(s) or other SLO/SLE constraint(s) that need to be met.

[0083] At **408**, the end-to-end controller **104** may send a transport slice request to the transport controller **110**. The transport slice request **408** may comprise the list. As noted above the list may include a fixed endpoint (e.g., endpoint A) and one or more candidate endpoint(s) (e.g., candidate endpoint X, candidate endpoint Y, and candidate endpoint Z). The list may further comprise latency constraints that the end-to-end controller **104** needs to meet, intent, or other information.

[0084] At **410**, the transport controller **110** may evaluate each candidate endpoint and each pathway for latency and may order the pathway(s) and/or candidate endpoint(s). For instance, the transport controller **110** may receive data from one or more transport devices within the transport network. The data may comprise real-time telemetry data. The transport controller **110** may evaluate, using the telemetry data and/or one or more machine learning models, each of the pathways to determine whether each pathway can meet the latency constraint(s) included in the transport slice request. The transport controller **110** may then order the pathways based on which pathway best meets the latency constraint (s). As an example, the latency constraint(s) may indicate that latency for a pathway needs to be less than 20 ms. The transport controller **110** may determine, based on the real-time telemetry data, that A to Y (e.g., from fixed endpoint A to candidate endpoint Y) has a latency greater than 20 ms, such that endpoint Y is rejected as not meeting the latency constraint. The transport controller **110** may determine pathways A to X (e.g., from fixed endpoint A to candidate endpoint X) and A to Z (e.g., from fixed endpoint A to candidate endpoint Z) each have a latency that is less than 20 ms, and thus do meet the latency constraints. The transport controller **110** may then order the pathways based on determining which pathway has the lowest latency time. For instance, pathway A to Z may have the lowest latency time when compared to pathways A to X and A to Y. Accordingly, pathway A to Z may be identified as the best pathway based on the latency constraints.

[0085] At **412**, the transport controller **110** may translate the intent into one or more additional constraint(s). As noted above, the intent may correspond to external intent of the end-to-end controller **104**. Accordingly, the transport controller **110** may translate the external intent into additional constraints, such as finding a pathway with the least number of hops. Additionally, the transport controller **110** may apply one or more internal network constraint(s), which may be based on internal information associated with the transport network (e.g., telemetry data, tunnel affinity, potential backup pathway(s), etc.). As noted above, the internal network constraint(s) may correspond to a current state of the transport network. For instance, the internal network constraint(s) may indicate a router in a pathway that is loaded, such that the transport controller **110** does not want a pathway to include the router. Additional information the transport controller may consider when determining the optimal pathway includes current and historical transport network traffic trends and/or internal analytics information (e.g., real-time telemetry data and internal analytics functions). As illustrated in FIG. **4**A, based on applying the intent(s), the transport controller **110** may determine that pathway A to X is the optimal pathway (e.g., despite pathway A to Z being best for latency conditions).

[0086] As illustrated in FIG. **4**B, at **414**, the transport controller **110** may provision the A to Z pathway as the best pathway for latency. As noted above, based on identifying the A to Z pathway as having the lowest latency time of the pathways and meeting the latency constraint(s), the transport controller **110** may dynamically and automatically provision the A to X pathway for the network slice. For instance, the transport controller **110** may make the connection between the fixed endpoint A and endpoint X available, such that the end-to-end controller **104** may deploy the UPF to endpoint X.

[0087] At **416**, the transport controller **110** may send a transport slice response to the end-to-end controller **104**. In some examples, the transport slice response **416** may comprise an indication of the provisioned pathway (e.g., "A to X pathway chosen") and a connection status of the pathway (e.g., "success").

[0088] At **418**, the end-to-end controller **104** may send a core slice request to the other subdomain controller(s) **402**. The core slice request **418** may indicate an endpoint (e.g., "location Z"). In some examples, location Z may correspond to endpoint Z. In some examples, the core slice request may correspond to a second network slice. The second network slice may be different from the network slice associated with the transport slice request **408**. In some examples, the second network slice may correspond to a second portion of the network slice associated with the slice provisioning request **404**.

[0089] At **420**, the end-to-end controller **104** may receive a core slice response from the other subdomain controller(s) **402**.

[0090] At **422**, the end-to-end controller **104** may send a slice provisioning response to the user device **102**. For instance, the slice provisioning response **422** may be sent to the customer facing controller of the user device **102**. In some examples, the slice provisioning response may comprise a status associated with whether the slice provisioning request **404** was completed. For example, the slice provisioning response **422** may indicate that the network slice was successfully provisioned.

[0091] Accordingly, the end-to-end controller may generate a transport slice request that comprises multiple candidate endpoints and then offloads the decision process to an intelligent network transport controller. In this way, the transport controller is better positioned to dynamically and automatically make a placement decision regarding the network slice, using data that is unavailable to the end-to-end orchestrator. Thus, the transport controller may utilize real-time network telemetry data (e.g., high CPUs, how many surfaces it has, how loaded it is, how much traffic is

going through it, etc.) from all transport devices in the pathway, historical information, and other analytic data, intent (external and internal intent) along with existing slice placement and reservation information, to dynamically select and provision the optimal pathway.

[0092] FIG. **5** illustrates a flow diagram of an example method **500** for a system to enable dynamic endpoint selection based on transport conditions. In some instances, the techniques may be performed by a system (e.g., one or more devices), such as the transport controller **110**, end-to-end controller **104**, a combination thereof, and/or any other devices (e.g., hardware offload chips and/or any other device). The techniques of method **500** may be performed by a system that includes one processor, or more than one processor.

[0093] At **502**, the system may receive a transport slice request from a network orchestrator. In some examples, the transport slice request may comprise a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints. In some examples, the transport controller and the transport network are included as part of a 5G network and the network orchestrator is an end-to-end controller within the 5G network. In some examples, the one or more constraints correspond to one or more service level objectives or service level expectations associated with a user.

[0094] In some examples, the transport slice request may correspond to a transport slice feasibility request, such as the transport slice feasibility request **308** described above.

[0095] In some examples, the network orchestrator generates the list in response to receiving a slice provisioning request from a user device, the list further comprising indications of specific constraints associated with each network slice.

[0096] At **504**, the system may receive from transport devices within a transport network, data associated with the transport network. In some examples, the data comprises telemetry data associated with the transport devices, historical data associated with the transport devices, and analytic data associated with the transport devices.

[0097] At **506**, the system may evaluate the candidate endpoint(s) for placement of a network slice. In some examples, the evaluating may be performed in real-time. In some examples, evaluating is based at least in part on utilizing a machine learning model, such as a YANG model. In some examples, the system may evaluate feasibility of each candidate endpoint based on the constraints.

[0098] In some examples, evaluating the one or more candidate endpoints further comprises evaluating each respective pathway from the fixed endpoint to each respective candidate endpoint based on the one or more constraints. In some examples, evaluating comprises determining, based at least in part on the evaluating, a best candidate pathway for the one or more constraints and provisioning the best candidate pathway.

[0099] At **508**, the system may send a transport slice response to the network orchestrator. In some examples, the transport slice response indicates that the best candidate pathway is selected and provisioned. In some examples, the transport slice response indicates a connection status associated with a candidate endpoint and/or a pathway.

[0100] In some examples, such as where the transport slice request comprises a feasibility request, the system may determine, based at least in part on evaluating each of the one or more candidate endpoints for feasibility based at least in part on the data and the one or more constraints, one or more feasible endpoints of the one or more candidate endpoints. In this example, the system may order the one or more feasible endpoints based at least in part on the one or more constraints. The system may send, to the network orchestrator, the transport slice response, the transport slice response indicating an order of the one or more feasible endpoints. The system may receive, from the network orchestrator, a second transport slice request comprising a selection of a feasible endpoint of the one or more feasible endpoints. The system may provision, based on the second transport slice request, a pathway from the fixed endpoint to the feasible endpoint.

[0101] FIG. **6** illustrates a flow diagram of an example method **600** for a system to enable a transport controller to dynamically evaluate and select a pathway based on various constraints and intents. In some instances, the techniques may be performed by a system (e.g., one or more devices), such as the transport controller **110**, end-to-end controller **104**, a combination thereof, and/or any other devices (e.g., hardware offload chips and/or any other device). The techniques of method **600** may be performed by a system that includes one processor, or more than one processor.

[0102] At **602**, the system may receive a transport slice request from a network orchestrator. In some examples, the transport slice request is associated with one or more network slices. In some examples, the transport slice request may comprise a list including a fixed endpoint, one or more candidate endpoints, a constraint, and one or more intents. In some examples, the transport controller and the transport network are included as part of a 5G network and the network orchestrator is an end-to-end controller within the 5G network.

[0103] At **604**, the system may receive from transport devices within a transport network, data associated with the transport network. In some examples, the data comprises telemetry data associated with the transport devices, historical data associated with the transport devices, and analytic data associated with the transport devices.

[0104] At **606**, the system may evaluate pathway(s) from a fixed endpoint to each candidate endpoint to determine an order of the pathways. In some examples, the evaluating may be performed in real-time. In some examples, evaluating is based at least in part on utilizing a machine learning model, such as a YANG model. In some examples, the system may evaluate feasibility of each candidate endpoint based on the constraints.

[0105] In some examples, evaluating the one or more candidate endpoints further comprises evaluating each respective pathway from the fixed endpoint to each respective candidate endpoint based on the one or more constraints. In some examples, evaluating comprises determining, based at least in part on the evaluating, a best candidate pathway for the one or more constraints and provisioning the best candidate pathway.

[0106] At **608**, the system may determine an optimal pathway between the fixed endpoint and a candidate endpoint. In some examples, the system may determine the optimal pathway based at least in part on the intent and/or second data of the transport controller. In some examples, the second data may comprise internal network constraints associated with the transport controller and analytic data associated with the transport controller.

[0107] In some examples, determining the optimal pathway may comprise: translating the intent into first constraints associated with the pathways; determining the internal network constraints, the internal network constraints comprising transport traffic trends; and applying the first constraints, the internal network constraints, and the analytic data to the pathways to determine the optimal pathway.

[0108] At **610**, the system may provision the optimal pathway for placement of a network slice. In some examples, the system may provision the optimal pathway automatically and in near real-time.

[0109] At **612**, the system may send a transport slice response to the network orchestrator. In some examples, the transport slice response may include an indication of the provisioned pathway and a connection status.

[0110] FIG. **7** shows an example computer architecture for a device capable of executing program components for implementing the functionality described above. The computer architecture shown in FIG. **7** illustrates any type of computer **700**, such as a conventional server computer, workstation, desktop computer, laptop, tablet, network appliance, e-reader, smartphone, or other computing device, and can be utilized to execute any of the software components presented herein. The computer may, in some examples, correspond to a transport controller **110**, end-to-end controller **104**, transport network device(s) **116**, and/or any other device described herein, and may comprise personal devices (e.g., smartphones, tables, wearable devices, laptop devices, etc.) networked devices such as servers, switches, routers, hubs, bridges, gateways, modems, repeaters, access points, and/or any other type of computing device that may be running any type of software and/or virtualization technology.

[0111] The computer **700** includes a baseboard **702**, or "motherboard," which is a printed circuit board to which a multitude of components or devices can be connected by way of a system bus or other electrical communication paths. In one illustrative configuration, one or more central processing units ("CPUs") **704** operate in conjunction with a chipset **706**. The CPUs **704** can be standard programmable processors that perform arithmetic and logical operations necessary for the operation of the computer **700**.

[0112] The CPUs **704** perform operations by transitioning from one discrete, physical state to the next through the manipulation of switching elements that differentiate between and change these states. Switching elements generally include electronic circuits that maintain one of two binary states, such as flip-flops, and electronic circuits that provide an output state based on the logical combination of the states of one or more other switching elements, such as logic gates. These basic switching elements can be combined to create more complex logic circuits, including registers, adders-subtractors, arithmetic logic units, floating-point units, and the like.

[0113] The chipset **706** provides an interface between the CPUs **704** and the remainder of the components and devices on the baseboard **702**. The chipset **706** can provide an interface to a RAM **708**, used as the main memory in the computer **700**. The chipset **706** can further provide an interface to a computer-readable storage medium such as a read-only memory ("ROM") **710** or non-volatile RAM ("NVRAM") for storing basic routines that help to startup the computer **700** and to transfer information between the various components and devices. The ROM **710** or NVRAM can also store other software components necessary for the operation of the computer **700** in accordance with the configurations described herein.

[0114] The computer **700** can operate in a networked environment using logical connections to remote computing devices and computer systems through a network, such as network(s) **106**. The chipset **706** can include functionality for providing network connectivity through a NIC **712**, such as a gigabit Ethernet adapter. The NIC **712** is capable of connecting the computer **700** to other computing devices over the network(s) **106**. It should be appreciated that multiple NICs **712** can be present in the computer **700**, connecting the computer to other types of networks and remote computer systems.

[0115] The computer **700** can be connected to a storage device **718** that provides non-volatile storage for the computer. The storage device **718** can store an operating system **720**, programs **722**, and data, which have been described in greater detail herein. The storage device **718** can be connected to the computer **700** through a storage controller **714** connected to the chipset **706**. The storage device **718** can consist of one or more physical storage units. The storage controller **714** can interface with the physical storage units through a serial attached SCSI ("SAS") interface, a serial advanced technology attachment ("SATA") interface, a fiber channel ("FC") interface, or other type of interface for physically connecting and transferring data between computers and physical storage units.

[0116] The computer **700** can store data on the storage device **718** by transforming the physical state of the physical storage units to reflect the information being stored. The specific transformation of physical state can depend on various factors, in different embodiments of this description. Examples of such factors can include, but are not limited to, the technology used to implement the physical storage units, whether the storage device **718** is characterized as primary or secondary storage, and the like.

[0117] For example, the computer **700** can store information to the storage device **718** by issuing instructions through the storage controller **714** to alter the magnetic characteristics of a particular location within a magnetic disk drive unit, the reflective or refractive characteristics of a particular location in an optical storage unit, or the electrical characteristics of a particular capacitor, transistor, or other discrete component in a solid-state storage unit. Other transformations of physical media are possible without departing from the scope and spirit of the present description, with the foregoing examples provided only to facilitate this description. The computer **700** can further read information from the storage device **718** by detecting the physical states or characteristics of one or more particular locations within the physical storage units.

[0118] In addition to the mass storage device **718** described above, the computer **700** can have access to other computer-readable storage media to store and retrieve information, such as program modules, data structures, or other data. It should be appreciated by those skilled in the art that computer-readable storage media is any available media that provides for the non-transitory storage of data and that can be accessed by the computer **700**. In some examples, the operations performed by the transport controller **110**, end-to-end controller **104**, transport network device(s) **116**, and/or any components included therein, may be supported by one or more devices similar to computer **700**. Stated other-

wise, some or all of the operations performed by the transport controller **110**, end-to-end controller **104**, transport network device(s) **116**, and or any components included therein, may be performed by one or more computers.

[0119] By way of example, and not limitation, computer-readable storage media can include volatile and non-volatile, removable and non-removable media implemented in any method or technology. Computer-readable storage media includes, but is not limited to, RAM,

[0120] ROM, erasable programmable ROM ("EPROM"), electrically-erasable programmable ROM ("EEPROM"), flash memory or other solid-state memory technology, compact disc ROM ("CD-ROM"), digital versatile disk ("DVD"), high definition DVD ("HD-DVD"), BLU-RAY, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store the desired information in a non-transitory fashion.

[0121] As mentioned briefly above, the storage device **718** can store an operating system **720** utilized to control the operation of the computer **700**. According to one embodiment, the operating system comprises the LINUX operating system. According to another embodiment, the operating system comprises the WINDOWS® SERVER operating system from MICROSOFT Corporation of Redmond, Washington. According to further embodiments, the operating system can comprise the UNIX operating system or one of its variants. It should be appreciated that other operating systems can also be utilized. The storage device **718** can store other system or application programs and data utilized by the computer **700**.

[0122] In one embodiment, the storage device **718** or other computer-readable storage media is encoded with computer-executable instructions which, when loaded into the computer **700**, transform the computer from a general-purpose computing system into a special-purpose computer capable of implementing the embodiments described herein. These computer-executable instructions transform the computer **700** by specifying how the CPUs **704** transition between states, as described above. According to one embodiment, the computer **700** has access to computer-readable storage media storing computer-executable instructions which, when executed by the computer **700**, perform the various processes described above with regard to FIGS. **1-6**. The computer **700** can also include computer-readable storage media having instructions stored thereupon for performing any of the other computer-implemented operations described herein.

[0123] The computer **700** can also include one or more input/output controllers **716** for receiving and processing input from a number of input devices, such as a keyboard, a mouse, a touchpad, a touch screen, an electronic stylus, or other type of input device. Similarly, an input/output controller **716** can provide output to a display, such as a computer monitor, a flat-panel display, a digital projector, a printer, or other type of output device. It will be appreciated that the computer **700** might not include all of the components shown in FIG. **7**, can include other components that are not explicitly shown in FIG. **7**, or might utilize an architecture completely different than that shown in FIG. **7**.

[0124] As described herein, the computer **700** may comprise one or more of a transport controller **110**, end-to-end controller **104**, transport network device(s) **116**, and/or any other device. The computer **700** may include one or more hardware processors (e.g., such as CPUs **704** (processors)) configured to execute one or more stored instructions. The processor(s) may comprise one or more cores. Further, the computer **700** may include one or more network interfaces configured to provide communications between the computer **700** and other devices, such as the communications described herein as being performed by the transport controller **110**, end-to-end controller **104**, transport network device(s) **116**, and/or any other device. The network interfaces may include devices configured to couple to personal area networks (PANs), user defined networks (UDNs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the network interfaces may include devices compatible with Ethernet, Wi-Fi™, and so forth.

[0125] The programs **722** may comprise any type of programs or processes to perform the techniques described in this disclosure for utilizing a transport controller to provide a critical mapping from intent to actual transport network characteristics when selecting and placing network slices. For instance, the programs **722** may cause the computer **700** to perform techniques including receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints. In some examples, the techniques include receiving, from transport devices within the transport network, data associated with the transport network. The techniques further include evaluating, based at least in part on the data and the transport slice request, the one or more candidate endpoints for placement of the network slice. The techniques also include sending, based at least in part on the evaluating, a transport slice response to the network orchestrator.

[0126] Additionally, or alternatively the programs **722** may cause the computer **700** to perform techniques including: receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, a constraint, and an intent. The techniques may include receiving, from transport devices within the transport network, data associated with the transport network. The techniques may include evaluating, based at least in part on the data and the transport slice request, pathways from the fixed endpoint to each candidate endpoint of the one or more candidate endpoints to determine an order of the pathways. The techniques may further include determining, based at least in part the intent and second data of the transport controller, an optimal pathway of the pathways between the fixed endpoint and a candidate endpoint. The techniques may also include provisioning, the optimal pathway from the fixed endpoint to the candidate endpoint for placement of the network slice. The techniques may include sending a transport slice response to the network orchestrator.

[0127] In this way, the techniques described herein enable an end-to-end controller to offload decisions about placement of network slices to the transport controller. By doing so, the transport controller can intelligently determine optimal placement based on intent (e.g., external intent of the end-to-end controller and internal intent of the transport controller), internal transport network analytics functions, SLO/SLE constraints, and real-time telemetry data, thereby providing dynamic and optimal placement of network slices.

That is the described techniques dynamically utilize information from within the transport domain to define the placement of network slices (e.g., such as in the 5GC or RAN domains). Thus, placements are more accurate, thereby reducing latency and improving functioning of the network, as well as providing an improved user experience by meeting SLO/SLE constraints.

[0128] While the invention is described with respect to the specific examples, it is to be understood that the scope of the invention is not limited to these specific examples. Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

[0129] Although the application describes embodiments having specific structural features and/or methodological acts, it is to be understood that the claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are merely illustrative some embodiments that fall within the scope of the claims of the application.

What is claimed is:

1. A method performed by a transport controller of a transport network, comprising:

receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints;

receiving, from transport devices within the transport network, data associated with the transport network;

evaluating, based at least in part on the data and the transport slice request, the one or more candidate endpoints for placement of the network slice; and

sending, based at least in part on the evaluating, a transport slice response to the network orchestrator.

2. The method of claim **1**, wherein the transport controller and the transport network are included as part of a 5G network and the network orchestrator is an end-to-end controller within the 5G network.

3. The method of claim **1**, wherein the transport slice request comprises a feasibility request, the method further comprising:

determining, based at least in part on evaluating each of the one or more candidate endpoints for feasibility based at least in part on the data and the one or more constraints, one or more feasible endpoints of the one or more candidate endpoints;

ordering the one or more feasible endpoints based at least in part on the one or more constraints;

sending, to the network orchestrator, the transport slice response, the transport slice response indicating an order of the one or more feasible endpoints;

receiving, from the network orchestrator, a second transport slice request comprising a selection of a feasible endpoint of the one or more feasible endpoints; and

provisioning, based on the second transport slice request, a pathway from the fixed endpoint to the feasible endpoint.

4. The method of claim **1**, wherein evaluating the one or more candidate endpoints further comprises evaluating each respective pathway from the fixed endpoint to each respective candidate endpoint based on the one or more constraints, the method further comprising:

determining, based at least in part on the evaluating, a best candidate pathway for the one or more constraints;

provisioning the best candidate pathway; and

sending the transport slice response, wherein the transport slice response indicates that the best candidate pathway is selected and provisioned.

5. The method of claim **1**, wherein the one or more constraints correspond to one or more service level objectives or service level expectations associated with a user.

6. The method of claim **1**, wherein the network orchestrator generates the list in response to receiving a slice provisioning request from a user device, the list further comprising indications of specific constraints associated with each network slice.

7. The method of claim **1**, wherein the data comprises telemetry data associated with the transport devices, historical data associated with the transport devices, and analytic data associated with the transport devices, and wherein the evaluating is performed in real-time.

8. The method of claim **1**, wherein evaluating is based at least in part on utilizing a machine learning model, such as a YANG model.

9. A system comprising:

one or more processors; and

non-transitory computer-readable media storing instructions that, when executed by the one or more processors, cause the system to perform operations comprising:

receiving, by a transport controller of a transport network and from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, and one or more constraints;

receiving, from transport devices within the transport network, data associated with the transport network;

evaluating, based at least in part on the data and the transport slice request, the one or more candidate endpoints for placement of the network slice; and

sending, based at least in part on the evaluating, a transport slice response to the network orchestrator.

10. The system of claim **9**, wherein the transport controller and the transport network are included as part of a 5G network and the network orchestrator is an end-to-end controller within the 5G network.

11. The system of claim **9**, wherein the transport slice request comprises a feasibility request, the operations further comprising:

determining, based at least in part on evaluating each of the one or more candidate endpoints for feasibility based at least in part on the data and the one or more constraints, one or more feasible endpoints of the one or more candidate endpoints;

ordering the one or more feasible endpoints based at least in part on the one or more constraints;

sending, to the network orchestrator, the transport slice response, the transport slice response indicating an order of the one or more feasible endpoints;

receiving, from the network orchestrator, a second transport slice request comprising a selection of a feasible endpoint of the one or more feasible endpoints; and

provisioning, based on the second transport slice request, a pathway from the fixed endpoint to the feasible endpoint.

12. The system of claim **9**, wherein evaluating the one or more candidate endpoints further comprises evaluating each respective pathway from the fixed endpoint to each respective candidate endpoint based on the one or more constraints, the operations further comprising:

determining, based at least in part on the evaluating, a best candidate pathway for the one or more constraints;

provisioning the best candidate pathway; and

sending the transport slice response, wherein the transport slice response indicates that the best candidate pathway is selected and provisioned.

13. The system of claim **9**, wherein the one or more constraints correspond to one or more service level objectives or service level expectations associated with a user.

14. The system of claim **9**, wherein the network orchestrator generates the list in response to receiving a slice provisioning request from a user device, the list further comprising indications of specific constraints associated with each network slice.

15. The system of claim **9**, wherein the data comprises telemetry data associated with the transport devices, historical data associated with the transport devices, and analytic data associated with the transport devices, and wherein the evaluating is performed in real-time.

16. The system of claim **9**, wherein evaluating is based at least in part on utilizing a machine learning model, such as a YANG model.

17. A method implemented by a transport controller of a transport network, comprising:

receiving, from a network orchestrator, a transport slice request associated with a network slice, the transport slice request comprising a list including a fixed endpoint, one or more candidate endpoints, a constraint, and an intent;

receiving, from transport devices within the transport network, data associated with the transport network;

evaluating, based at least in part on the data and the transport slice request, pathways from the fixed endpoint to each candidate endpoint of the one or more candidate endpoints to determine an order of the pathways;

determining, based at least in part the intent and second data of the transport controller, an optimal pathway of the pathways between the fixed endpoint and a candidate endpoint;

provisioning, the optimal pathway from the fixed endpoint to the candidate endpoint for placement of the network slice; and

sending a transport slice response to the network orchestrator.

18. The method of claim **17**, wherein the second data comprises internal network constraints associated with the transport controller and analytic data associated with the transport controller.

19. The method of claim **18**, wherein determining the optimal pathway further comprises:

translating the intent into first constraints associated with the pathways;

determining the internal network constraints, the internal network constraints comprising transport traffic trends; and

applying the first constraints, the internal network constraints, and the analytic data to the pathways to determine the optimal pathway.

20. The method of claim **17**, wherein the transport controller and the transport network are included as part of a 5G network and the network orchestrator is an end-to-end controller within the 5G network.

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