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Inventor(s)	SHARMA; Anuj et al.

TRAFFIC MANAGEMENT TO REDUCE CELLULAR NETWORK OUTAGES

Abstract

A traffic orchestrator reduced cellular network outages via improved traffic management. The orchestrator receives network management logs and call logs from network nodes and uses them, along with key performance indicators (KPIs) for network nodes, traffic patterns, and network topology, to identify nodes that are operating in a degraded manner, or are not fit for traffic. The orchestrator generates and distributes traffic advisories to various network nodes. This rebalances traffic to reduce losses to traffic throughput, such as by rerouting traffic around degraded nodes and nodes that are not fit for traffic. This proactive approach occurs prior to a network node being reported as unavailable to a network repository (e.g., a 5G NRF), and not only enables some of the degraded nodes an opportunity to recover prior to an outage (reducing outages), but also reroutes traffic prior to impending outages, reducing the effect on users when outages

Inventors: **SHARMA; Anuj (Broadlands, VA), BELWAL; Deepesh (Ashburn, VA), MARIYANI; Anil Kumar (Ashburn, VA)**

Applicant: **T-Mobile USA, Inc.** (Bellevue, WA)

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Background/Summary

BACKGROUND

[0001] Modern wireless networks (e.g., cellular networks) are implemented using a plethora of different networking nodes working in tandem to provide wireless services to large numbers of customers. The various networking nodes interact with each other on different interfaces (northbound/southbound/sideways) to keep the traffic flowing connected over a TCP/IP network.

[0002] A primary challenge in providing seamless, reliable service to users arises as a result of different networking nodes experiencing different types of degradation issues due to hardware, software, and networking faults, or a combination. This often results in disruption of services which is either corrected automatically, using network resilience measures such as failover routes, or by manual intervention.

[0003] In current cellular networks, such as 5G, in addition to some network nodes performing their own local resilience measures, a network resource function (NRF) tracks network node availability as a network resilience measure. If the NRF detects that a network node has become unavailable, such as by a reported outage, a loss of a "heartbeat" signal, or a failure to respond to a repeated ping, the NRF marks the network node as unsuitable for handling traffic. The NRF will no longer identify that unavailable node to other network nodes requesting a resource. Even if the process of identifying a newly-unavailable network node is rapid, to minimize the number of other network nodes that are steered to it, and moving traffic to alternate network nodes (e.g., failover routes) is rapid, this process is still reactive. Network users whose traffic had been passing through the newly-unavailable network node may have noticed a performance degradation, such as dropped packets or delays, leading to poor user experiences.

SUMMARY

[0004] The following summary is provided to illustrate examples disclosed herein, but is not meant to limit all examples to any particular configuration or sequence of operations.

[0005] Solutions are disclosed that provide improved traffic management to reduce cellular network outages. Examples include: receiving network management logs from network nodes of a wireless network; receiving call logs from network nodes of the wireless network; using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and key performance indicators (KPIs) for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and distributing the traffic advisories to network nodes of the wireless network.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The disclosed examples are described below with reference to the accompanying drawing figures listed below, wherein:

[0007] FIG. **1** illustrates an exemplary architecture that advantageously improve traffic management to reduce cellular network outages;

[0008] FIG. **2** illustrates an alternative representation of the wireless network of FIG. **1**;

[0009] FIG. **3** illustrates example messages used in examples of the architecture of FIG. **1**;

[0010] FIG. **4** illustrates a scenario of rebalancing traffic in the wireless network of FIG. **1**;

[0011] FIG. **5** illustrates further detail for the traffic orchestrator of FIG. **1**;

[0012] FIGS. **6** and **7** illustrate flowcharts of exemplary operations associated with the architecture of FIG. **1**; and

[0013] FIG. **8** illustrates a block diagram of a computing device suitable for implementing various aspects of the disclosure.

[0014] Corresponding reference characters indicate corresponding parts throughout the drawings. References made throughout this disclosure, relating to specific examples, are provided for illustrative purposes, and are not meant to limit all implementations or to be interpreted as excluding the existence of additional implementations that also incorporate the recited features.

DETAILED DESCRIPTION

[0015] A traffic orchestrator reduced cellular network outages via improved traffic management. The orchestrator receives network management logs and call logs from network nodes and uses them, along with key performance indicators (KPIs) for network nodes, traffic patterns, and network topology, to identify nodes that are operating in a degraded manner, or are not fit for traffic. The orchestrator generates and distributes traffic advisories to various network nodes. This rebalances traffic to reduce losses to traffic throughput, such as by rerouting traffic around degraded nodes and nodes that are not fit for traffic. This proactive approach occurs prior to a network node being reported as unavailable to a network repository (e.g., a 5G NRF), and not only enables some of the degraded nodes an opportunity to recover prior to an outage (reducing outages), but also reroutes traffic prior to impending outages, reducing the effect on users when outages do occur.

[0016] Some examples further identify anomalies in call logs, such as missing call event logs, which could lead to security issues and/or revenue leak (e.g., an unauthorized subscriber using the network). In such cases, additional traffic advisories are generated and distributed to initiate an automatic corrective action for the identified anomaly (e.g., trigger network nodes to address the missing call event) or generate an alert for a network operations center (NOC) so that the issue may be addressed in a timely manner. Some examples use artificial intelligence (AI) or machine learning (ML), used effectively synonymously here, for the identifications of impending outages and/or call log anomalies and also may use AI/ML for the generation of the traffic advisories. Some examples are capable of self-learning, starting with a set of programmed rules, and then improving over time as network responses to traffic advisories are monitored and further train the AI/ML of the orchestrator.

[0017] Aspects of the disclosure improve the reliability of cellular networks by proactively identifying impending outages and rerouting traffic around (or away from) nodes that are operating in a degraded manner and nodes that are not fit for traffic, before a catastrophic outage occurs and is reported to a network repository. This reduces impact on network users by permitting some of the network nodes to recover without failing entirely (as a result of reduced traffic), and further moves traffic prior to an outage which would otherwise have negative impacts on users whose traffic had been passing through the failed node. These advantageous results are accomplished, at least in part by, using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and KPIs for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput.

[0018] With reference now to the figures, FIG. **1** illustrates an exemplary architecture **100** that advantageously improves traffic management to reduce cellular network outages. A wireless network **110** is illustrated that is serving a UE **102**. UE **102** may be a cellular telephone, such as a smartphone, but may also represent other telecommunication devices capable of using a wireless network, such as a personal computer (PC, e.g., desktop, notebook, tablet, etc.) with a cellular modem. In the scene depicted in FIG. **1**, UE **102** is using wireless network **110** for a packet data session to reach a network resource **126** (e.g., a website) across an external packet data network **124** (e.g., the internet). In some scenarios, UE **102** may use wireless network **110** for a phone call with another UE **122**. Wireless network **110** may be a cellular network such as a fifth generation (5G) network, a fourth generation (4G) network, or another cellular generation network.

[0019] UE **102** uses an air interface **106** to communicate with a base station **111** of wireless network **110**, such that base station **111** is the serving base station for UE **102** (providing the serving cell). In some scenarios, base station **111** may be referred to as a radio access network (RAN). Wireless network **110** has an access node **113**, a session management node **114**, a traffic orchestrator **500**, and other components (not shown). Wireless network **110** also has a packet routing node **116** and a proxy node **117**. Access node **113** and session management node **114** are within a control plane **200** of wireless network **110**, and packet routing node **116** is within a data plane **210** of wireless network **110** (as shown in FIG. **2**).
[0020] Base station **111** is in communication with access node **113** and packet routing node **116**. Access node **113** is in communication with session management node **114**, which is in communication with packet routing node **116** and proxy node **117**. Packet routing node **116** is in communication with proxy node **117**, and packet data network **124**. In some 5G examples, base station **111** comprises a gNodeB (gNB), access node **113** comprises an access mobility function (AMF), session management node **114** comprises a session management function (SMF), and packet routing node **116** comprises a user plane function (UPF).
[0021] In some 4G examples, base station **111** comprises an eNodeB (eNB), access node **113** comprises a mobility management entity (MME), session management node **114** comprises a system architecture evolution gateway (SAEGW) control plane (SAEGW-C), and packet routing node **116** comprises an SAEGW-user plane (SAEGW-U). In some examples, proxy node **117** comprises a proxy call session control function (P-CSCF) in both 4G and 5G.
[0022] In some examples, wireless network **110** has multiple ones of each of the components illustrated, in addition to other components and other connectivity among the illustrated components. In some examples, wireless network **110** has components of multiple cellular technologies operating in parallel in order to provide service to UEs of different cellular generations. For example, wireless network **110** may use both a gNB and an eNB co-located at a common cell site. In some examples, multiple cells may be co-located at a common cell site, and may be a mix of 5G and 4G.
[0023] Proxy node **117** is in communication with an internet protocol (IP) multimedia system (IMS) access gateway (IMS-AGW) **120** within an IMS, in order to provide connectivity to other wireless (cellular) networks, such as for a call with UE **122** or a public switched telephone system (PSTN, also known as plain old telephone system, POTS). In some examples, proxy node **117** may be considered to be within the IMS. UE **102** reaches network resource **126** using packet data network **124** (or IMS-AGW **120**, in some examples). Data packets from UE **102** pass through at least base station **111** and packet routing node **116** on their way to packet data network **124** or IMS-AGW **120** (via proxy node **117**).
[0024] Traffic orchestrator **500** identifies when a network node of wireless network **110** is operating in a degraded manner, or is not fir for traffic and generates and distributes traffic advisories for rebalancing traffic in wireless network **110**, to reduce losses to traffic throughput, as described in further detail below. In some examples, also described in further detail below, traffic orchestrator **500** further identifies anomalies in call log data and generates and distributes additional traffic advisories to initiate an automatic corrective actions.
[0025] Although FIG. **1** and some of the following figures are described using an example of a cellular network, it should be understood that the teachings herein are applicable to other types of wireless networks. Any wireless network that uses a backhaul with multiple network nodes, at least some of which maintain event logs, nodes may also benefit from the teachings herein. In such other network types, traffic orchestrator **500** monitors KPIs of the backhaul network nodes and harvests their event logs.
[0026] FIG. **2** illustrates an alternative representation of wireless network **110**, using 5G names for network nodes. Control plane **200** includes traffic orchestrator **500**, a unified data repository (UDR) **201**, a network exposure function (NEF) **202**, a network repository **203** shown as a network

function (NF) repository function (NRF), a policy control function (PCF) **204**, an application function (AF) **205**, access node **113** shown as an AMF), a unified data management (UDM) **206**, an unstructured data storage function (UDSF) **207**, a network slice selection function (NSSF) **208**, session management node **114** shown as an SMF, and a service communication proxy (SCP) **209**. In some examples, control plane **200** has multiple ones of each of the nodes shown (see FIG. **3**), as well as additional types of nodes (not shown), such as a home subscriber server (HSS), a telephony application server (TAS), and others.

[0027] A second base station **112** also shown for wireless network **110**, which is also in communication with access node **113**. Wireless network **110** may have a larger number of base stations. Data plane **210** includes packet routing node **116** shown as a UPF, and in some examples is referred to as a user plane. Traffic orchestrator **500** is in communication with all of nodes **111-113**, **114**, **116**, and **201-209** for receiving logs and distributing traffic advisories.

[0028] FIG. **3** illustrates example messages used in examples of architecture **100**. Traffic orchestrator **500** receives network management logs **330** and call logs **332** from network nodes **300** of wireless network **110**. Network nodes **300** is shown as a set of nodes **111-113**, **114**, **116**, and **201-209**, with multiple ones shown for each of nodes **113**, **114**, **116**, and **201-209**. (A larger number of base stations may also be used). In some examples, network management logs **330** comprise fault, configuration, accounting, performance and security (FCAPS) logs for network nodes of wireless network **110**. Call logs **332** is shown as having an anomaly **333**, which is identified and corrected as described below in relation to FIG. **5**. Examples of anomaly **333** include a missing push profile request from an HSS to a TAS, and a missing cancel location request (CLR) that should have been sent to access node **113**.

[0029] Traffic orchestrator **500** has an orchestration engine **320** that identifies degraded nodes (network nodes operating in a degraded manner) and network nodes that are not fit for traffic, and call event anomalies such as anomaly **333**, and generates traffic advisories **340** in response. Traffic advisories **340** includes health advisories **341** for rebalancing traffic in wireless network **110** to reduce losses to traffic throughput and call event advisories **342** to initiate automatic corrective actions for identified call event anomalies.

[0030] Traffic orchestrator **500** distributes traffic advisories **340** to network nodes **300**, as shown in further detail in FIG. **4**. In some examples, traffic orchestrator **500** also generates an alert **344** in response to anomaly **333** and transmits it to a NOC **350** for other corrective action. In some examples, traffic orchestrator **500** is located within NOC **350**, and/or the at least some of the functionality described herein for traffic orchestrator **500** is distributed among multiple nodes of wireless network **110**.

[0031] Orchestration engine **320** uses criteria **310** for identifying a network node (of network nodes **300**) as degraded, and criteria **315** for identifying a network node as not fit for traffic. Criteria **310** may include a processor load threshold **311**, a memory usage threshold **312**, and/or a storage usage threshold **313**. Criteria **315** may include a processor load threshold **316**, a memory usage threshold **317**, a storage usage threshold **318**, and an identification of an alarm **319** (one or more) that indicates a relatively serious condition.

[0032] Initially, criteria **310** and **315** may be set based on the experience of network operators. In some examples, orchestration engine **320** uses AI/ML that intake criteria **310** and **315** as input. A self-learning component **322** monitors whether failures actually occur following a node meeting criteria **310** or **315** (as well as other KPIs) and is able to further train orchestration engine **320** to improve its diagnosis of degraded nodes and nodes that are unfit for traffic. In such examples, criteria **310** and **315** may change over time to improve the ability of orchestration engine **320** to predict failures.

[0033] Additionally, orchestration engine **320** is initially programmed to generate and distribute traffic advisories **340** to select ones of network nodes **300**, based on the experience of network operators. Self-learning component **322** also monitors responses of network nodes to traffic

advisories **340**, to identify which traffic advisories **340** and traffic advisory contents produce superior results, and further train orchestration engine **320** to improve traffic advisory contents and selection of network nodes **300** for receiving distribution of traffic advisories **340**.

[0034] In an example, initially-programmed criteria **310** may include processor load threshold **311** set to a CPU exceeding 60% load for more than one minute, memory usage threshold **312** set to memory usage exceeding 65% for more than one minute, storage usage threshold **313** set to disk usage exceeding 75%, and traffic volume exceeding the configured limit for more than two minutes. Initially-programmed criteria **315** may include processor load threshold **316** set to a CPU exceeding 60% load for more than three minutes, memory usage threshold **317** set to memory usage exceeding 65% for more than three minutes, storage usage threshold **318** set to disk usage exceeding 85%, alarm **319** indicating some set of possible alarms related to network node health, and traffic volume exceeding the configured limit for more than two minutes.

[0035] FIG. **4** illustrates a scenario **400** of rebalancing traffic in wireless network **110** by rerouting traffic around (away from) degraded nodes and/or nodes that are not fit for traffic, as represented by traffic **410** and a network node **402** (shown as a degraded node). Network node **402** may be any of the nodes of network nodes **300** of FIG. **3**.

[0036] Initially, a network node **404** and a network node **406** are both using network node **402** for traffic **410**. Network nodes **404** and **406** may collectively be referred to as other network nodes **408** of wireless network **110** that are using network node **402**. Although two network nodes are shown as using network node **402** for traffic **410**, some examples may have more.

[0037] Traffic orchestrator **500** transmits (distributes) an initial set of health advisories **341** to network nodes **408** (network node **404** and network node **406**) upon determining that network node **402** is operating in a degraded manner. In response, network node **404** and network node **406** each reroute a portion **412** of traffic **410** away from network node **402** to alternate route **414** through an alternate node **420**. In some examples, health advisories **341** identifies the percentage of traffic to reroute or a new maximum amount of traffic **410** that may continue to be routed to network node **402**.

[0038] Upon determining that network node **402** is not fit for traffic, traffic orchestrator **500** transmits (distributes) another set of health advisories **341** to network nodes **408**. In response, network node **404** and network node **406** each reroute all of traffic **410** away from network node **402** to alternate route **414** through an alternate node **420**. Additionally, a health advisory **341** is sent to network repository **203** to alert network repository **203** that network node **402** is unavailable. Network repository **203** holds availability information for network nodes of wireless network **110**. When other network nodes of wireless network **110** need a resource, they consult network repository **203**. If network repository **203** no longer lists network node **402** as available, no other network nodes of wireless network **110** will use network node **402**. In some examples, traffic orchestrator **500** alerts network repository **203** that network node **402** is unavailable upon network node **402** entering a degraded state of operation.

[0039] Upon determining that network node **402** is once again fit for traffic and no longer operating in a degraded manner, traffic orchestrator **500** transmits (distributes) another set of health advisories **341** to network nodes **408** and network repository **203**. Other nodes of wireless network **110** are now able to use network node **402** in normal operations.

[0040] FIG. **4** also shows traffic orchestrator **500** transmitting call event advisories **342** to a network node **416** that needs to perform an automatic corrective action for anomaly **333**, such as deregistering an unauthorized user or initiating a network node event missing from call logs **332**. This capability is able to plug revenue leaks that may otherwise occur if unauthorized sessions are not terminated, and improve network security by reducing the access by unauthorized users.

[0041] FIG. **5** illustrates further detail for traffic orchestrator **500**. A set of log receivers **502** receives network management logs **330** and call logs **332** for traffic orchestrator **500** from network nodes **300**, and a set of advisory distributors **504** transmits traffic advisories **340** to selected ones of

network nodes **300**. An extract, transform, load (ETL) process **506** to transform network management logs **330** and call logs **332** into a form used for storage in a database **510**.

[0042] In some examples, database **510** also has KPIs **511**, traffic patterns **512** of wireless network **110**, and network topology **513** of wireless network **110**. In some examples, KPIs **511** include alarms; processor, memory usage, and storage usage data; and transactions per unit time. Network topology **513** has information about network nodes **300** and relationships among the network nodes. In some examples, database **510** also stores health decision configuration **514**, which is information used by orchestration engine **320** to generate health advisories **341**. For example, criteria **310** and criteria **315** may be part of health decision configuration **514**, and health decision configuration **514** may be updated by either user inputs **530** or improved by self learning component **322**. In some examples, database **510** also stores call flow decision configuration **515**, which is information used by orchestration engine **320** to generate call event advisories **342**. Call flow decision configuration **515** may updated by either user inputs **530** or improved by self learning component **322**.

[0043] Orchestration engine **320** pulls information from database **510** as needed, and also receives inputs in the form of user inputs **530** (e.g., specific instructions from users related to routing traffic through wireless network **110**) an operations management reporting **532**. For example, some of KPIs **511**, and information about alarms from network nodes **300** may be received through operations management reporting **532**, if not received from network management logs **330**. That is, information needed to identify whether any network nodes meet criteria **310** or criteria **315** is received through the combination of network management logs **330** and operations management reporting **532**.

[0044] Orchestration engine **320** is illustrated as having a health check processing component **520** that generates health advisories **341**, and a call events processing component **522** that generates call event advisories **342**. Some examples may use a different architecture for orchestration engine **320**. After generation, health advisories **341** and call event advisories **342** move to advisory distributors **504** for distribution to selected ones of network nodes **300**.

[0045] There are multiple use cases for traffic orchestrator **500**, including rebalancing traffic based on processor usage (i.e., lessening the burden on network nodes that have heavy processor loads by moving traffic to lesser-burdened network nodes), rebalancing traffic based on service response time (i.e., routing traffic away from network nodes reporting higher traffic delays (lower transactions per unit time) toward network nodes reporting lower traffic delays), and deregistering unauthorized users.

[0046] This third use case may be described with an example scenario: Traffic orchestrator **500** receives information of a provisioning event for deactivation of a registered user, and determines (based on call logs **332**) that a deregister event (Nudm_UECM_DeregNotification) should be sent from UDM **206** to AMF **113**, and then AMF **113** should initiate an unsubscribe for subscriber data (Nudm_SDM_Unsubscribe). However, traffic orchestrator **500** identifies, from call logs **332**, that UDM **206** did not send the deregister event to AMF **113**. Traffic orchestrator **500** then sends a call event advisory **342** to UDM **206**, instructing UDM **206** to initiate a forced deregistration sequence. Traffic orchestrator **500** logs this action and notes it in alert **344** to NOC **350**.

[0047] In some examples, traffic orchestrator **500** is able to track and correlate such events and identify trends, such as certain nodes repeatedly produce certain types of anomalies, or anomalies are correlated with certain areas or events. By issuing another alert **344** to NOC **350**, such systematic issues may be identified and addressed by the operators of wireless network **110**.

[0048] FIG. **6** illustrates a flowchart **600** of exemplary operations associated with examples of architecture **100**. In some examples, at least a portion of flowchart **600** may be performed using one or more computing devices **800** of FIG. **8**. Flowchart **600** commences with traffic orchestrator **500** receiving network management logs **330** from network nodes **300** in operation **602**, and receiving call logs **332** from network nodes **300** in operation **604**.

[0049] Operation **606** performs ETL process **506** to transform network management logs **330** and call logs **332** into a form used for storage in database **510**, and operation **608** persists network management logs **330** and call logs **332** in database **510**. In some examples, operation **608** further persists KPIs **511** in database **510**, such as alarms; processor, memory usage, and storage usage data; and transactions per unit time.

[0050] In operation **610**, orchestration engine **320** retrieves network management logs **330**, call logs **332**, KPIs **511**, traffic patterns **512**, and network topology **513** from database **510**, and call log data from different call logs are associated by subscriber in operation **612**. In operation **614**, orchestration engine **320** identifying anomaly **333** in call logs **332** for a particular subscriber. Based on at least identifying anomaly **333**, orchestration engine **320** generates one or more call event advisories **342** to initiate an automatic corrective action for anomaly **333**, and/or generates alert **344**, in operation **616**.

[0051] In some examples, the automatic corrective action comprises deregistering an unauthorized user or initiating a network node event that is missing from call logs **332** (the call log data). Operation **618** transmits alert **344** to NOC **350**.

[0052] Flowchart **600** performs the next operations **620** and **622** in parallel with operations **612**-**618**. In operation **620**, orchestration engine **320** identifies that network node **402** is operating in a degraded manner, for example using criteria **310** along with network management logs **330**, call logs **332**, traffic patterns **512**, network topology **513**, and KPIs **511**. Orchestration engine **320** generates health advisories **341** in operation **622**. In operation **624**, traffic orchestrator **500** distributes traffic advisories **340** (health advisories **341** and call event advisories **342**) to select ones of network nodes **300**. For example, health advisories **341** are distributed to other network nodes **408** of wireless network **110**, that are using network node **402**, to steer at least portion **412** of traffic **410** away from network node **402** to alternate route **414** (thereby rebalancing traffic in wireless network **110**). Call event advisories **342** are distributed to network nodes that need to perform an automatic corrective action for anomaly **333** (e.g., node **416**).

[0053] Traffic **410** is rerouted and the corrective action for anomaly **333** is performed in operation **626**. Decision operation **628** determines whether network node **402** has recovered. If traffic orchestrator **500** identifies that network node **402** is no longer operating in a degraded manner in decision operation **628**, traffic orchestrator **500** generates and distributes further traffic advisories **340** indicating that network node **402** is no longer operating in a degraded manner, in operation **630**. Other network nodes **408** may then resume routing the full allocation of traffic **410** to network node **402**.

[0054] If network node **402** has not recovered, decision operation **632** determines whether network node **402** is fit for traffic. If so, flowchart **600** returns to decision operation **628** to monitor network node **402** for recovery or remaining in a degraded state. If, however, orchestration engine **320** identifies that network node **402** is not fit for traffic in decision operation **632**, flowchart **600** moves to operation **634**. Orchestration engine **320** may use criteria **315** along with network management logs **330**, call logs **332**, traffic patterns **512**, network topology **513**, and KPIs **511** in decision operation **632**.

[0055] Based on at least identifying that network node **402** is not fit for traffic, traffic orchestrator **500** generates and distributes further traffic advisories **340** (health advisories **341**) to other network nodes **408** to steer all traffic away from network node **402** to alternate route **414**, in operation **634**. Traffic **410** is fully rerouted in operation **636**. In operation **638**, traffic orchestrator **500** identifies to network repository **203** that network node **402** is unavailable. Network repository **203** marks network node **402** as unavailable and will not assign network node **402** to any new traffic sessions until network node **402** recovers.

[0056] In decision operation **640**, traffic orchestrator **500** determines whether network node **402** is available and no longer operating in a degraded manner. If not, flowchart **600** remains at decision operation **640**, at least with respect to network node **402**. When traffic orchestrator **500** (performing

decision operation **640**) identifies that network node **402** is available and is not operating in a degraded manner, traffic orchestrator **500** identifies to network repository **203** that network node **402** is available, in operation **642**.

[0057] In operation **644**, self-learning component **322** monitors conditions of wireless network **110** subsequent to distributing traffic advisories **340**, and orchestration engine **320** performs self-learning to improve determination of when and/or where to distribute a traffic advisory and/or to improve traffic advisory content, in operation **646**.

[0058] FIG. **7** illustrates a flowchart **700** of exemplary operations associated with examples of architecture **100**. In some examples, at least a portion of flowchart **700** may be performed using one or more computing devices **800** of FIG. **8**. Flowchart **700** commences with operation **702**, which includes receiving network management logs from network nodes of a wireless network.

[0059] Operation **704** includes receiving call logs from network nodes of the wireless network. Operation **706** includes using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and KPIs for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput. Operation **708** includes distributing the traffic advisories to network nodes of the wireless network.

[0060] FIG. **8** illustrates a block diagram of computing device **800** that may be used as any component described herein that may require computational or storage capacity. Computing device **800** has at least a processor **802** and a memory **804** that holds program code **810**, data area **820**, and other logic and storage **830**. Memory **804** is any device allowing information, such as computer executable instructions and/or other data, to be stored and retrieved. For example, memory **804** may include one or more random access memory (RAM) modules, flash memory modules, hard disks, solid-state disks, persistent memory devices, and/or optical disks. Program code **810** comprises computer executable instructions and computer executable components including instructions used to perform operations described herein. Data area **820** holds data used to perform operations described herein. Memory **804** also includes other logic and storage **830** that performs or facilitates other functions disclosed herein or otherwise required of computing device **800**. An input/output (I/O) component **840** facilitates receiving input from users and other devices and generating displays for users and outputs for other devices. A network interface **850** permits communication over external network **860** with a remote node **870**, which may represent another implementation of computing device **800**. For example, a remote node **870** may represent another of the above-noted nodes within architecture **100**.

Additional Examples

[0061] An example traffic orchestrator for a wireless network comprises: a set of log receivers comprising a network management log receiver and a call log receiver, wherein the network management log receiver receives network management logs from network nodes of the wireless network, and wherein the call log receiver receives call logs from network nodes of the wireless network; an orchestration engine operable to receive the network management logs and the call logs via the set of log receivers and use the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and KPIs for network nodes of the wireless network to generate traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and a traffic advisor operable to distribute the traffic advisories to network nodes of the wireless network.

[0062] An example system comprises: a processor; and a computer-readable medium storing instructions that are operative upon execution by the processor to:

[0063] An example method of wireless communication comprises: receiving network management logs from network nodes of a wireless network; receiving call logs from network nodes of the wireless network; using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and KPIs for network nodes of the wireless

network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and distributing the traffic advisories to network nodes of the wireless network.

[0064] One or more example computer storage devices has computer-executable

[0065] instructions stored thereon, which, upon execution by a computer, cause the computer to perform operations comprising: receiving network management logs from network nodes of a wireless network; receiving call logs from network nodes of the wireless network; using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and KPIs for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and distributing the traffic advisories to network nodes of the wireless network.

[0066] Alternatively, or in addition to the other examples described herein, examples include any combination of the following: [0067] persisting at least the network management logs and the call logs in a database; [0068] retrieving the network management logs, the call logs, and the network topology from the database; [0069] performing an ETL process to transform the network management logs and the call logs into a form used for storage in the database; [0070] associating call log data from different call logs by subscriber; [0071] identifying an anomaly in call log data for a particular subscriber; [0072] based on at least identifying the anomaly, generating a traffic advisory to initiate an automatic corrective action for the identified anomaly or generating an alert; [0073] monitoring conditions of the wireless network subsequent to distributing the traffic advisories; [0074] performing self-learning to improve determination of when and/or where to distribute a traffic advisory; [0075] performing self-learning to improve traffic advisory content; [0076] identifying that the first network node of the wireless network is operating in a degraded manner; [0077] based on at least identifying that the first network node of the wireless network is operating in a degraded manner, generating and distributing traffic advisories to other network nodes of the wireless network, that are using the first network node, to steer at least a portion of traffic away from the first network node to an alternate route; [0078] identifying that the first network node is no longer operating in a degraded manner; [0079] based on at least identifying that the first network node of the wireless network is no longer operating in a degraded manner, generating and distributing traffic advisories indicating that the first network node is no longer operating in a degraded manner; [0080] identifying that the first network node is not fit for traffic; [0081] based on at least identifying that the first network node of the wireless network is not fit for traffic, generating and distributing traffic advisories to the other network nodes, that are using the first network node, to steer all traffic away from the first network node to an alternate route; [0082] based on at least identifying that the first network node of the wireless network is not fit for traffic, identifying to a network repository, that holds availability information for network nodes of the wireless network, that the first network nodes is unavailable; [0083] identifying that the first network node is available and not operating in a degraded manner; [0084] based on at least identifying that the first network node of the wireless network available and not operating in a degraded manner, identifying to the network repository that the first network node is available; [0085] the traffic orchestrator is operable to persist at least the network management logs and the call logs in a database; [0086] the orchestration engine receives the network management logs, the call logs, and the network topology from the database; [0087] the ETL process is disposed between the set of log receivers and the database; [0088] the ETL process is operable to transform information received from the set of log receivers to a form used for storage in the database; [0089] the traffic orchestrator is operable to associate call log data from different call logs by subscriber; [0090] the traffic orchestrator is operable to identify an anomaly in call log data for a particular subscriber; [0091] the traffic orchestrator is operable to, based on at least identifying the anomaly, generate a traffic advisory to initiate an automatic corrective action for the identified anomaly or generate an alert; [0092] the traffic orchestrator is operable to monitor conditions of the wireless

network subsequent to distributing the traffic advisories; [0093] the orchestration engine is operable to perform self-learning to improve determination of when and/or where to distribute a traffic advisory; [0094] the orchestration engine is operable to perform self-learning to improve traffic advisory content; [0095] the network management logs comprise FCAPS logs for network nodes of the wireless network; [0096] the centralized traffic orchestrator comprises the database; [0097] the orchestration engine comprises ML and/or AI; [0098] the automatic corrective action comprises deregistering an unauthorized user; [0099] the automatic corrective action comprises initiating a network node event missing from the call log data for the particular subscriber; [0100] the orchestration engine further receives the traffic patterns and KPIs from the database; [0101] the orchestration engine associates the call log data from different call logs by subscriber; [0102] the orchestration engine identifies the anomaly in the call log data for a particular subscriber; the orchestration engine generates the traffic advisory to initiate the automatic corrective action; [0103] the traffic advisories comprise health advisories and call event advisories; [0104] the health advisories rebalance traffic in the wireless network; [0105] the call event advisories initiate automatic corrective actions for the identified anomalies in the call log data; [0106] the KPIs include alarms; processor, memory usage, and storage usage data; and transactions per unit time; [0107] criteria for identifying a network node as degraded include a first processor load threshold, a first memory usage threshold, and/or a first storage usage threshold; [0108] criteria for identifying a network node as not fit for traffic include a second processor load threshold, a second memory usage threshold, a second storage usage threshold, and/or an alarm; [0109] transmitting the alert to a NOC; [0110] the network repository comprises an NRF; and [0111] the wireless network comprises a 5G cellular network.

[0112] The order of execution or performance of the operations in examples of the disclosure illustrated and described herein is not essential, unless otherwise specified. That is, the operations may be performed in any order, unless otherwise specified, and examples of the disclosure may include additional or fewer operations than those disclosed herein. For example, it is contemplated that executing or performing a particular operation before, contemporaneously with, or after another operation is within the scope of aspects of the disclosure. It will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments. When introducing elements of aspects of the disclosure or the examples thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. The term “exemplary” is intended to mean “an example of.”

[0113] Having described aspects of the disclosure in detail, it will be apparent that modifications and variations are possible without departing from the scope of aspects of the disclosure as defined in the appended claims. As various changes may be made in the above constructions, products, and methods without departing from the scope of aspects of the disclosure, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Claims

1. A method of wireless communication, the method comprising: receiving network management logs from network nodes of a wireless network; receiving call logs from network nodes of the wireless network; using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and key performance indicators (KPIs) for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and distributing the traffic advisories to network nodes of the wireless network.

2. The method of claim 1, further comprising: persisting at least the network management logs and the call logs in a database; and retrieving the network management logs, the call logs, and the network topology from the database.
3. The method of claim 2, further comprising: performing an extract, transform, load (ETL) process to transform the network management logs and the call logs into a form used for storage in the database.
4. The method of claim 1, further comprising: associating call log data from different call logs by subscriber; identifying an anomaly in call log data for a particular subscriber; and based on at least identifying the anomaly, generating a traffic advisory to initiate an automatic corrective action for the identified anomaly or generating an alert.
5. The method of claim 1, further comprising: monitoring conditions of the wireless network subsequent to distributing the traffic advisories; and either: performing self-learning to improve determination of when and/or where to distribute a traffic advisory; or performing self-learning to improve traffic advisory content.
6. The method of claim 1, further comprising: identifying that a first network node of the wireless network is operating in a degraded manner; based on at least identifying that the first network node of the wireless network is operating in a degraded manner, generating and distributing traffic advisories to other network nodes of the wireless network, that are using the first network node, to steer at least a portion of traffic away from the first network node to an alternate route; identifying that the first network node is no longer operating in a degraded manner; and based on at least identifying that the first network node of the wireless network is no longer operating in a degraded manner, generating and distributing traffic advisories indicating that the first network node is no longer operating in a degraded manner.
7. The method of claim 6, further comprising: identifying that the first network node is not fit for traffic; based on at least identifying that the first network node of the wireless network is not fit for traffic, generating and distributing traffic advisories to the other network nodes, that are using the first network node, to steer all traffic away from the first network node to an alternate route and identifying to a network repository, that holds availability information for network nodes of the wireless network, that the first network nodes is unavailable; identifying that the first network node is available and not operating in a degraded manner; and based on at least identifying that the first network node of the wireless network available and not operating in a degraded manner, identifying to the network repository that the first network node is available.
8. A traffic orchestrator for a wireless network, the traffic orchestrator comprising: a set of log receivers comprising a network management log receiver and a call log receiver, wherein the network management log receiver receives network management logs from network nodes of the wireless network, and wherein the call log receiver receives call logs from network nodes of the wireless network; an orchestration engine operable to receive the network management logs and the call logs via the set of log receivers and use the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and key performance indicators (KPIs) for network nodes of the wireless network to generate traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and a traffic advisor operable to distribute the traffic advisories to network nodes of the wireless network.
9. The traffic orchestrator of claim 8, wherein the traffic orchestrator is operable to persist at least the network management logs and the call logs in a database, and wherein the orchestration engine receives the network management logs, the call logs, and the network topology from the database.
10. The traffic orchestrator of claim 9, further comprising: an extract, transform, load (ETL) process disposed between the set of log receivers and the database, operable to transform information received from the set of log receivers to a form used for storage in the database.
11. The traffic orchestrator of claim 8, wherein the traffic orchestrator is further operable to: associate call log data from different call logs by subscriber; identify an anomaly in call log data

for a particular subscriber; and based on at least identifying the anomaly, generate a traffic advisory to initiate an automatic corrective action for the identified anomaly or generate an alert.

12. The traffic orchestrator of claim 8, wherein the traffic orchestrator is further operable to: monitor conditions of the wireless network subsequent to distributing the traffic advisories; and wherein the orchestration engine is further operable to either: perform self-learning to improve determination of when and/or where to distribute a traffic advisory; or perform self-learning to improve traffic advisory content.

13. The traffic orchestrator of claim 8, wherein the traffic orchestrator is further operable to: identify when a first network node of the wireless network is operating in a degraded manner; based on at least identifying that the first network node of the wireless network is operating in a degraded manner, generate and distribute traffic advisories to other network nodes of the wireless network, that are using the first network node, to steer at least a portion of traffic away from the first network node to an alternate route; identify when the first network node is no longer operating in a degraded manner; and based on at least identifying that the first network node of the wireless network is no longer operating in a degraded manner, generate and distribute traffic advisories indicating that the first network node is no longer operating in a degraded manner.

14. The traffic orchestrator of claim 13, wherein the traffic orchestrator is further operable to: identify when the first network node is not fit for traffic; based on at least identifying that the first network node of the wireless network is not fit for traffic, generate and distribute traffic advisories to the other network nodes, that are using the first network node, to steer all traffic away from the first network node to an alternate route and identify to a network repository, that holds availability information for network nodes of the wireless network, that the first network nodes is unavailable; identify when the first network node is available and not operating in a degraded manner; and based on at least identifying that the first network node of the wireless network available and not operating in a degraded manner, identify to the network repository that the first network node is available.

15. One or more computer storage devices having computer-executable instructions stored thereon, which, upon execution by a computer, cause the computer to perform operations comprising: receiving network management logs from network nodes of a wireless network; receiving call logs from network nodes of the wireless network; using the network management logs, the call logs, traffic patterns of the wireless network, network topology of the wireless network, and key performance indicators (KPIs) for network nodes of the wireless network, generating traffic advisories for rebalancing traffic in the wireless network to reduce losses to traffic throughput; and distributing the traffic advisories to network nodes of the wireless network.

16. The one or more computer storage devices of claim 15, wherein the operations further comprise: persisting at least the network management logs and the call logs in a database; and retrieving the network management logs, the call logs, and the network topology from the database.

17. The one or more computer storage devices of claim 16, wherein the operations further comprise: performing an extract, transform, load (ETL) process to transform the network management logs and the call logs into a form used for storage in the database.

18. The one or more computer storage devices of claim 15, wherein the operations further comprise: associating call log data from different call logs by subscriber; identifying an anomaly in call log data for a particular subscriber; and based on at least identifying the anomaly, generating a traffic advisory to initiate an automatic corrective action for the identified anomaly or generating an alert.

19. The one or more computer storage devices of claim 15, wherein the operations further comprise: monitoring conditions of the wireless network subsequent to distributing the traffic advisories; and either: performing self-learning to improve determination of when and/or where to distribute a traffic advisory; or per forming self-learning to improve traffic advisory content.

20. The one or more computer storage devices of claim 15, wherein the operations further

comprise: identifying that a first network node of the wireless network is operating in a degraded manner; based on at least identifying that the first network node of the wireless network is operating in a degraded manner, generating and distributing traffic advisories to other network nodes of the wireless network, that are using the first network node, to steer at least a portion of traffic away from the first network node to an alternate route; identifying that the first network node is not fit for traffic; and based on at least identifying that the first network node of the wireless network is not fit for traffic, generating and distributing traffic advisories to the other network nodes, that are using the first network node, to steer all traffic away from the first network node to an alternate route and identifying to a network repository, that holds availability information for network nodes of the wireless network, that the first network nodes is unavailable.