

METHOD AND SYSTEM FOR EXTENDING 5G SERVICE

FIELD OF INVENTION

[0001] The present invention relates broadly, but not exclusively, to methods and systems of extending 5G service to a remote ground terminal.

BACKGROUND

[0002] Typically, 5G services are only available to devices attached to a 5G network, therefore any device that is needed to utilize a 5G service, such as a network slice, must be 5G attached to a cellular network. Current 5G networks, despite being broadly deployed, still encounter several shortcomings. The main challenges include: (i) service continuity, where terrestrial 5G networks alone cannot provide sufficient coverage for a 5G service; and (ii) service ubiquity across unserved or under-served areas.

[0003] Therefore, a need exists to provide methods and systems of extending 5G service to a remote ground terminal.

SUMMARY

[0004] According to a first aspect of the present invention, there is provided a method of extending 5G service to a remote ground terminal, including: establishing an interface between an existing 5G cellular network and a core network, wherein a gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network; executing a UE emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal; and establishing end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network.

[0005] According to a second aspect of the present invention, there is provided system for extending 5G service to a remote ground terminal, comprising: an interface module configured to establish an interface between an existing 5G cellular network and a core network, wherein a gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network; an emulation module configured to execute a UE

emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal; and a communication module configured to establish end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[0007] Figure 1 is a schematic of a system for extending 5G service, according to one embodiment of the invention.

[0008] Figure 2 is a schematic of a remote ground terminal, according to one embodiment of the invention.

[0009] Figure 3 shows a flow diagram illustrating an exemplary method of extending 5G service to a remote ground terminal, according to one embodiment of the invention.

[0010] Figure 4 shows a schematic diagram of a system for extending 5G service to a remote ground terminal, according to one embodiment of the invention.

[0011] Figure 5 shows a schematic diagram of an exemplary computing device used to realise a system for extending 5G service to a remote ground terminal, according to one embodiment of the invention.

DETAILED DESCRIPTION

[0012] Embodiments of the present invention will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[0013] Some portions of the description which follows are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of operations on data within a computer memory. These algorithmic descriptions and functional or symbolic

representations are the means used by those skilled in the data processing arts to convey most effectively the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

[0014] Unless specifically stated otherwise, and as apparent from the following, it will be appreciated that throughout the present specification, discussions utilizing terms such as “scanning”, “calculating”, “determining”, “replacing”, “generating”, “initializing”, “outputting”, or the like, refer to the action and processes of a computer system, or similar electronic device, that manipulates and transforms data represented as physical quantities within the computer system into other data similarly represented as physical quantities within the computer system or other information storage, transmission or display devices.

[0015] The present specification also discloses apparatus for performing the operations of the methods. Such apparatus may be specially constructed for the required purposes, or may comprise a computer or other device selectively activated or reconfigured by a computer program stored in the computer. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various machines may be used with programs in accordance with the teachings herein. Alternatively, the construction of more specialized apparatus to perform the required method steps may be appropriate. The structure of a conventional computer will appear from the description below.

[0016] In addition, the present specification also implicitly discloses a computer program, in that it would be apparent to the person skilled in the art that the individual steps of the method described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the spirit or scope of the invention.

[0017] Furthermore, one or more of the steps of the computer program may be performed in parallel rather than sequentially. Such a computer program may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a computer. The computer readable medium may also include a hard-wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in the GSM, GPRS, 3G or 4G mobile telephone systems, as well as other wireless systems such as Bluetooth, ZigBee, Wi-Fi. The computer program when loaded and executed on such a computer effectively results in an apparatus that implements the steps of the preferred method.

[0018] In the following description, the term "module" can refer to software, a hardware element, or a combination of both.

[0019] The present invention may also be implemented as hardware modules. More particularly, in the hardware sense, a module is a functional hardware unit designed for use with other components or modules. For example, a module may be implemented using discrete electronic components, or it can form a portion of an entire electronic circuit such as an Application Specific Integrated Circuit (ASIC) or Field Programmable Gate Array (FPGA). Numerous other possibilities exist. Those skilled in the art will appreciate that the system can also be implemented as a combination of hardware and software modules.

[0020] An Application Programming Interface (API) enables software and applications to communicate with each other. It is a software-to-software interface that allows for separate parties to communicate with each other without any previous user knowledge or intervention. In general terms, it is a set of clearly defined methods of communication between various software components.

[0021] This specification uses the term "configured to" in connection with systems, apparatus, and computer program components. For a system of one or more computers to be configured to perform particular operations or actions means that the system has installed on its software, firmware, hardware, or a combination of them that in operation cause the system to perform the operations or actions. For one or more computer programs to be configured to perform particular operations or actions means that the one or more programs include instructions that, when executed by data processing apparatus, cause the apparatus to perform the operations or actions. For special-

purpose logic circuitry to be configured to perform particular operations or actions means that the circuitry has electronic logic that performs the operations or actions.

[0022] Embodiments of the invention seek to enable devices that are not 5G attached to a cellular network to be part of the 5G services offered by the 5G network. Specifically, devices that are not in range of a 5G network can use a transit network to “extend” 5G services between the 5G cellular network and the remote device.

[0023] In implementations of the invention, the transit networks are neutral, meaning any technology can be used to implement the transit network, such as satellite, fiber, and/or microwave.

[0024] Since 5G services require devices to be on a 5G network that use the service, the biggest problem is extending the 5G radio interface. This can be accomplished by adding more cells or increasing the size of a cell. Adding more 5G cells is cost prohibitive in environments where the average revenue per user does not justify the expense of adding the infrastructure required to turn up a new 5G cell. 3GPP is also defining 5G over satellite, where the satellite acts as a base station and 5G waveforms are used over satellite, extensively increasing the size of a 5G cell.

[0025] Additionally, high-altitude platform stations are used to increase the size of a cell since they are effectively very high base stations. However, there are line-of-sight limitations caused by the curvature of the Earth.

[0026] Embodiments of the invention seek to solve the problems associated with extending 5G networks by adding more cells or higher base stations to overcome RF line of sight limitations. Embodiments of the invention convert the 5G interface from a layer 1 RF interface to a layer 3 packet interface, which can then traverse any media capable of supporting layer 3 packet protocol services.

[0027] Additionally, using 5G waveforms over satellite turn the satellite service into a 5G cellular network, making it comply within the tightly controlled rules and regulations all governments have in place for cellular networks. Embodiments of the invention use satcom traditional waveforms over satellite for transit networks, therefore not turning the satellite network into a cellular network.

[0028] Embodiments of the invention interface to a gNodeB (5G base station) using industry standard interfaces for extending gNodeB services into cloud-based solutions. This is done to emulate 5G user equipment, and not to extend the base station

capabilities into a cloud service. In this manner, far end ground terminals are represented as a 5G user equipment on an incumbent mobile network operator (MNO)'s 5G network. A transit network is used to establish end-to-end communication between a remote ground terminal and the mobile operator's gNodeB. To the mobile operator's gNodeB, the ground terminal appears as any other 5G user equipment attached to their cellular network.

[0029] Additionally, embodiments of the invention integrate a 5G cellular modem into the ground terminal, with a mobile operator's physical SIM or eSIM. The cellular modem is connected to the 5G network when it is in range of the network, and when it is not, the SIM is used for mobility management procedures such as subscriber authentication. The physical SIM interface is extended to support software-based authentication.

[0030] Embodiments of the invention seek to provide the following advantages:

1. Does not require the mobile operator to extend the RF range of their network
2. Any device outside the 5G RF range of a mobile operator can operate as if it is on the 5G network, therefore extending 5G services
3. 5G services can be extended outside a country without requiring regulatory support
4. Any device without a cellular modem can utilize 5G services
5. Does not require costly NTN solutions over satellite for regional and global coverage
6. Cost effective solution for extending 5G
7. Can utilize any technology for the transit network
8. Provides least cost routing of user plane traffic

[0031] Figure 1 is a schematic of a system for extending 5G service, according to one embodiment of the invention. The system comprises three domains – (i) Core Network Domain, (ii) Transit Network Domain, and (iii) Ground Terminal Domain – each with a series of subsystems. The domains are typically physically separate from each other, with the Transit Network domain providing interconnectivity services.

[0032] The Core Network domain provides operational, business, customer, and cellular support systems. These support systems provide the overall capabilities to add/remove accounts, customize services, and mobility management, along with managing the Transit Network and Ground Terminal domain resources.

[0033] The Transit Network domain provides the physical and data communication paths between the Core Network domain and the Ground Terminal domain. It is a multi-strata communication network, providing services for user and control plane data.

[0034] The Ground Terminal domain provides gateway services for end devices, along with providing advanced communication services such as multi-path bonding and least cost routing. The Ground Terminal domain converts physical, data link, and network services between end devices, cellular networks, and the Transit Network domain.

[0035] Core Network Domain

The core network domain comprises the following subsystems:

[0036] 1. Customer Portal

The Customer Portal subsystem manages the stream of user plane data to and from the customer. The user plane data may use any type of IP protocol, such as RTP. Additionally, this subsystem includes encryption and authentication services for the user plane data streams.

[0037] 2. Web Interface

The Web Interface subsystem is a web service providing an HTTPS service for customer access. Additionally, this subsystem includes server-side processing, a database, and a processing shim for interfacing and converting APIs within the BSS and OSS. These APIs enable, modify, monitor, and manage services throughout the Core Network, Transit Network, and Ground Terminal domains.

The Web Interface may include additional customer interfaces, such as email, chat protocols, and cellular SMS.

The Web Interface may also contain web-based UI enabling access to performance management, configuration management, accounting, security and fault management services, covering all three domains. The portal interfaces to other services within the Core Network Domain through the Business Support System (BSS) and Operational Support System (OSS). The BSS and OSS includes a set of APIs used by the Customer Portal subsystem. These APIs include accessing subsystems within the Ground Terminal domain.

[0038] 3. User Plane Interface

The User Plane Interface subsystem is a data link switching and network routing service for user plane traffic originating and terminating with the end user. This traffic is transported to/from the Ground Terminal domain via the Transit Network domain or the 5G interface.

[0039] 4. *Business Support System (BSS)*

The Business Support System (BSS) is the backbone of customer-facing and revenue-related processes. By integrating customer management, billing, service provisioning, and quality assurance, the BSS ensures that customers receive their expected services. Additionally, the customer is provided data to ensure the services are billed accurately. The BSS also provides the administrator of the system the tools to monitor and improve customer experience and revenue generation.

Specifically, the BSS manages customer accounts. It is a subsystem used by the administrator of the system to manage customers, customer configurations, billing packages, usage restrictions, traffic flows, network level (applies to one or more customers), user plane routes, control plane routes, etc.

The BSS interfaces with all Core Network domain subsystems, typically through the operational support system. The BSS includes a set of APIs used by the customer portal to expose configuration capabilities to end customers.

The BSS includes a database storing customer account, usage, history, and access information. The BSS manages the business processes and customer-facing activities associated with the operations of the system. It provides services enabling customer management, billing, service assurance, and resource optimization, in order to deliver the user plane services efficiently and reliably.

[0040] Key components and functions of the BSS:

- Customer Management and CRM

Customer Onboarding: Assists with the registration, authentication, and initial setup for new customer accounts.

Account Management: Stores customer data, including contact information, service details, service usage history, and support tickets.

Customer Relationship Management (CRM): Tracks and manages customer interactions, monitors satisfaction, and supports customer retention through proactive engagement and support.

APIs: Provides API supporting the Web Interface to enable customers viewing their account information, manage services, track service status and monitor performance.

- Billing and Revenue Management

Usage-Based Billing: Calculates charges based on data usage, speed, priority of data, and/or quality of service.

Subscription and Recurring Billing: Manages recurring service plans, providing automated invoicing, billing cycles, and renewals.

Real-Time Charging: Offers real-time charging capabilities, particularly useful for services having data limits, ensuring that usage beyond a certain threshold is charged accordingly.

Invoicing and Payment Processing: Generates invoices, handles payment processing (credit card, bank transfer, etc.), and manages billing disputes.

Revenue Assurance: Monitors for revenue leaks, ensuring all services provided are properly billed.

- Order and Service Management

Order Fulfilment: Tracks and manages orders for hardware and services, such as Ground Terminals, SIMs, and 5G service. Additionally, this function seeks to ensure hardware and services are delivered, installed, and configured correctly.

Service Provisioning: Coordinates with the Operational Support System (OSS) to activate, deactivate, or modify services offered by the Core Network domain and the Ground Terminal domain as per customer needs.

Configuration Management: Allows customization of services according to different customer tiers (e.g., basic vs. premium data plans) and ensures customers receive their chosen configurations.

- Service Assurance and Quality Monitoring

Monitoring and Alerts: Tracks key performance indicators (KPIs) for network quality, uptime, and satellite link quality, helping to ensure reliable service.

Troubleshooting and Support: Integrates with a ticketing system to track support issues, monitor resolution times, and keep customers informed about the status of their issues.

SLAs (Service Level Agreements): Tracks performance against SLAs and proactively addresses any issues affecting promised quality or uptime to customers.

Proactive Maintenance: Identifies and addresses network issues before they impact customers, often by using machine learning algorithms to detect patterns that indicate potential faults.

- Resource and Capacity Management

Bandwidth Allocation and Management: Allocates and optimizes bandwidth based on user demand, service plans, and geographical needs. Ensures that customers with higher service tiers receive prioritized access if bandwidth becomes limited.

Resource Utilization Analytics: Provides insights into network utilization and performance, helping administrators to understand customer demand patterns and optimize resource allocation.

Capacity Planning: Supports long-term planning by forecasting demand and scaling resources (e.g., bandwidth, satellite transponders) to prevent service degradation as the customer base grows.

Transit Network Domain Routing: Allocates, manages, and monitors routing across all the Transit Network domain paths, along with the 5G interface.

- Product and Service Management

Product Catalogue: A digital library of all service offerings, packages, and pricing options, allowing quick changes to accommodate customer requests.

Service Bundling and Customization: Enables the creation of bundled services, allowing customers to customize their package according to their needs.

Promotions and Discounts: Manages promotional campaigns and discount programs to attract new customers and retain existing ones.

- Analytics and Reporting

Usage Reports: Provides customers with detailed reports on their data usage, helping them manage their consumption and prevent unexpected charges.

Financial Analytics: Tracks revenue, churn rates, average revenue per user (ARPU), and other financial metrics to assess business performance.

Customer Insights: Analyses data on customer usage patterns, support history, and satisfaction, helping the administrator tailor services and improve customer experience.

Usage: The billing system tracks usage by account, ground terminal, and device connected to the ground terminal across the system and across the various user plane routes. Additionally, the billing system tracks usage to/from the gNodeB by UE, i.e. ground terminal.

- Security and Compliance Management

Data Security: Ensures all customer data and transactions are protected using encryption and compliance with relevant data protection regulations.

Access Control: Implements strict access controls to ensure only authorized personnel can access or modify sensitive BSS data.

Regulatory Compliance: Ensures adherence to telecommunications regulations, including data retention and lawful interception requirements.

Integration with OSS (Operational Support System): The BSS works closely with the OSS, which manages the technical aspects of the network and service delivery. The BSS initiates a service activation request, and the OSS completes the technical activation within the Core Network domain. Service performance data collected by the OSS feeds into the BSS for billing, reporting, and quality monitoring.

- Billing

Billing is a subsystem within the BSS. Billing interfaces with usage data managed by the Performance Management subsystem to enforce billing rules and the resulting impacts to services used by a customer and ground terminal based on the billing data. The Billing subsystem is also used to provision user accounts and to define usage rules for ground terminals.

Billing rules are customized usage enforcement rules that take usage, location of ground terminals, time of day, priority, real-time network usage, and end device data as input to determine the priority and variable bit rate for a ground terminal. These rules are implemented within the BSS as modules, enabling new services overtime. Additionally, these models allow the BSS to evolve to support new services withing the Transit Network and Ground Terminal domains.

This subsystem also manages customer specific information that impacts billing, such as currency type, billing period, and service types.

[0041] 5. Operational Support System (OSS)

The Operational Support System (OSS) comprises multiple subsystems. The OSS interfaces with internal and external subsystems. It provides a set of APIs to be used by the BSS to manage the system services, user plane traffic, and control plane traffic. The OSS converts proprietary interfaces between all the Core Network domain subsystems to a standard set of interfaces for the BSS and customer portal.

The OSS interfaces with the BSS and Web interface subsystem. The OSS is used to provision and manage the subsystems designed to interface with all subsystems as

described herein, for provisioning and managing of the system. The OSS supports chain provisioning and rollback of complex provisioning tasks. It also manages rolling up of faults into system level faults and also clearing of these faults.

[0042] Each subsystem within the OSS is described below.

- Performance Management subsystem

This subsystem collects data from the BSS, OSS, UE Emulation, Cellular Network, Transit Domain, ESA, ACU, Satcom Modem, Cellular Modem, GNSS and CPU subsystems and stores the data in a relational database. This subsystem also processes the data to create customer defined key performance indicators, which are tracked on a regular time basis, such as by minute, hour, day, and month. Additionally, this subsystem supports monitoring of the collected data, to include system and customer defined triggers that result in alerts and faults. These alerts and faults are then forwarded to the Customer via the Web Interface subsystem.

- Configuration Management subsystem

This subsystem receives high-level API calls from the BSS and OSS subsystem and converts them into low level API calls and messaging for every subsystem and service. This subsystem translates API calls and messages, it supports roll-back for configurations, blocking of configuration changes for services that are in use, and manages configuration errors between all subsystems.

Configuration management involves systematically managing and controlling the setup, settings, and operational parameters of the Core Network domain and the devices within the Ground Terminal domain. This includes ensuring that each subsystem, route, and, and ground terminal are correctly configured according to operational requirements, security policies, and customer service levels.

[0043] *Key Capabilities of Configuration Management*

a. Initial Setup and Deployment:

Device Provisioning: Configuring each ground terminal with the necessary parameters (e.g., IP addresses, frequency settings, bandwidth allocations) before deployment. This setup is typically done in accordance with the customer's service plan.

Parameter Standardization: Ensuring that all ground terminals within the system adhere to a standardized configuration template, which minimizes discrepancies and errors.

b. Configuration Changes and Updates:

Dynamic Reconfiguration: Allows for real-time changes to parameters (such as bandwidth, modulation, or error correction) based on customer requirements, network conditions, or changing service levels.

Software and Firmware Updates: Manages updates to the system's software, such as the satellite modem software and firmware to enhance performance, security, and compatibility.

c. Automated Configuration Management: Some configurations may be automated, allowing the system to adjust parameters based on policies or real-time data (e.g., allocating more bandwidth to high-priority users during peak usage).

d. Monitoring and Compliance:

Status Monitoring: Continuously monitors configurations to ensure all subsystems are running within specified parameters and immediately alerts administrators if settings cross predefined thresholds.

Configuration Audits: Regularly audits settings across the system to ensure compliance with operational standards, security protocols, and regulatory requirements.

Backup and Recovery: Maintains backups of configuration files, allowing for quick restoration in case of system failure, accidental misconfiguration, or cyber threats.

e. Policy Enforcement and Security:

Access Controls: Manages which users or automated systems can make configuration changes, minimizing the risk of unauthorized access or accidental misconfiguration.

Configuration Policies: Enforces rules for specific parameters (such as encryption settings or traffic prioritization) to ensure consistency across devices, maintain security, and meet SLA requirements.

f. Customer-Specific Configuration:

Service-Level Adjustments: Adjusts configurations for individual customers based on their service plan (e.g., higher bandwidth or lower latency for premium services).

User-Specific Profiles: Creates profiles for different customer types, allowing the system to apply preset configurations quickly.

g. Documentation and Change Management:

Change Logs: Tracks and documents all configuration changes, recording the user who made each change, why it was made, and when.

Configuration Documentation: Maintains detailed documentation on the standard configuration settings, ground terminal firmware, and software versions used throughout the system.

[0044] Benefits of Configuration Management in a Satellite Modem Hub

Reliability and Consistency: By ensuring that ground terminals operate under uniform configurations, configuration management minimizes disruptions and inconsistencies.

Efficiency: Enables quick deployment of new ground terminals, streamlined reconfigurations, and simplified troubleshooting, enhancing the overall operational efficiency of the system.

Security: Regular monitoring and access controls help protect configurations from unauthorized changes, reducing vulnerabilities.

Service Quality: Helps ensure each ground terminal and connection operates as expected, delivering a consistent quality of service to end-users.

Scalability: Makes it easier to manage large, complex networks with many ground terminals and configurations, essential as the network grows or adjusts to more demanding user needs.

In summary, configuration management for the system is the systematic approach to setting up, maintaining, and securing the operational parameters of the system. It helps keep the ground terminals performing reliably, securely, and in line with customer and operational expectations.

[0045] 6. Mobility Management

The Mobility Management subsystem tracks the location of the ground terminals and provides mobility management services including ground terminal authentication, assignment of Transit Network Domain resources, management of SIMs, hand-off of transit services from one physical interface type to another, e.g. transponder beams, encryption of data for ground terminals, and the management of cellular services for the ground terminals.

The Mobility Management subsystem communicates with the Communication Hub subsystem for the control and assignment of satellite resources supported by the ground terminals, based on the ground terminal's location, allowed services, and customer provisioned data within the BSS.

The Mobility Management subsystem also interfaces with the UE Emulation subsystem to provide mobility management services compatible with 5G mobile networking services. This enables the ground terminals to act as UEs on the MNO's network.

[0046] 7. Accounting

The Accounting subsystem supports managing ground station, cellular services, Transit Network domain, and user plane services. The Accounting subsystem maintains its own datastore services.

Accounting services include tracking, recording, and reporting on data usage and system network activity for connected ground terminals. These services are essential in monitoring network usage patterns, managing bandwidth, enforcing policies, and supporting billing processes.

[0047] Key Aspects of Router Accounting Services

a. Traffic and Usage Monitoring:

Data Usage Tracking: Tracks the amount of data sent and received by each ground terminal and network type across the system. This helps in understanding which ground stations or end devices are consuming the most bandwidth.

Packet Counting: Counts the number of packets sent and received throughout the system and by ground terminal, which is used by the Performance Management subsystem.

Session Monitoring: Records details for each network session and data tunnel, including session start and end times, duration, and data volume. This is used by the BSS and Performance Management subsystems.

b. User and Device Identification:

Ground terminal Address Logging: Logs IP and MAC addresses associated with network traffic for each ground terminal.

End Device Identification: Associates data usage with specific end for services where end device security is required.

c. Bandwidth Management:

Quota Enforcement: Tracks data usage against preset quotas (e.g., data limits) for ground terminals, enforcing restrictions if a limit is reached.

Usage Alerts: Sends alerts when certain usage thresholds are crossed, which helps network administrators and users monitor consumption and prevent overuse.

d. Billing and Cost Allocation:

Usage-Based Billing: Accounting data is used to charge customers based on their data usage. Usage records from the Accounting subsystem are fed into the BSS to generate accurate billing reports.

Cost Allocation: Accounting services attribute costs to different transit networks, ground terminals and, enabling a more detailed view of network resource usage.

e. Policy Enforcement:

Quality of Service (QoS) Monitoring: Tracks the types of traffic within the Transit Network domain, helping ensure QoS policies are enforced according to the system priorities set by the administrator.

Access Control: Enforce access policies by limiting or logging specific types of traffic, ground terminals, or end devices, aiding in network security and compliance.

f. Reporting and Analysis:

Usage Reports: Generates detailed reports on network usage patterns, which can be segmented by end device, ground terminal, time period, or transit network type. These reports provide insights for capacity planning and network optimization.

Trend Analysis: Analyzes historical data to identify usage trends, helping system administrators forecast future needs and make informed decisions about scaling or optimizing the system.

g. Security and Compliance Logging:

Audit Logs: Records network activity, supporting security audits by tracking actions like device connections, disconnections, or unauthorized access attempts.

Compliance Reporting: Collect accounting logs for verifying compliance with data handling, security, and privacy regulations.

h. Integration with Network Management Systems:

SNMP (Simple Network Management Protocol): Manage SNMP Management Information Base (MIB) to collect and transmit accounting data to centralized network management systems.

AAA Integration: Enabling a AAA (Authentication, Authorization, and Accounting) framework, allowing ground terminals and end devices to integrate seamlessly with other

authentication and authorization systems for a comprehensive security and monitoring approach.

In summary, the accounting subsystem is used for tracking and managing network activity, supporting billing and cost management, enforcing policies, and maintaining security and compliance.

[0048] 8. Security

The Security subsystem provides ground station and customer portal authentication services. It also manages encryption keys for user plane and control traffic between the Core Network domain and the Ground Terminal domain. The Security subsystem also maintains its own database and stores authentication key material within it.

[0049] Key Aspects of the Security subsystem

a. Access Control and Authentication:

Authentication: Ensures that only authorized software modules can access the ground terminal's configuration and operational settings. This includes password protection, user roles, and permissions to restrict access to sensitive configurations.

Role-Based Access Control (RBAC): Controls access levels based for API roles, ensuring that only authorized API calls can perform high-level configurations and critical changes.

b. Data Encryption:

User Plane Encryption: Encrypts user plane data sent between the Ground Terminal domain and the Core Network domain. Common encryption protocols include AES (Advanced Encryption Standard) and IPsec (Internet Protocol Security).

Control Plane Encryption: Encrypts control plane data sent between the Ground Terminal domain and the Core Network domain. Common encryption protocols include AES (Advanced Encryption Standard) and IPsec (Internet Protocol Security).

c. Logging and Auditing:

Event Logging: Records all significant events, such as login attempts, configuration changes, and firmware updates, allowing administrators to monitor for unusual activity.

Audit Trails: Keeps a record of all actions performed on the ground terminal for accountability and forensic analysis in the event of a security incident.

Real-Time Alerts: Generates alerts for critical security events, such as failed login attempts or configuration changes, enabling quick response to potential threats.

d. Resilience and Failover:

Backup Connections: Command the ground terminal to switch to an alternative communication path if/when the primary path is compromised.

Redundancy: Command ground terminals configured with redundancy to switch to standby hardware and software in the case of failure or compromise.

[0050] 9. UE Emulation

The UE Emulation subsystem provides all necessary mobility management services required for a 5G mobile subscription to attach to a 5G network and park on a cell. This also includes the ability to move between cells, service areas, and networks. In a 5G network, mobility management functions ensure seamless connectivity, service continuity, and optimized network performance as a User Equipment (UE), which in embodiments of the invention is manifested as a ground terminal, moves across different cells, network slices, or geographical areas.

[0051] The ground terminals within the Ground Terminal domain are virtual UEs within the MNO's network via the gNodeB interface. Each ground terminal acts as a UE parked on the cell represented by the gNodeB. This enables devices connected to the ground terminal to gain access to all features and capabilities of the 5G network, hence resulting in the extension of the 5G network. As such, references to a UE and ground terminal are synonymous in this description.

[0052] This subsystem represents each ground station as an emulated UE within the MNO network. This allows a 5G network slice to access the ground terminal via 5G data service. The user plane data path traverses through the 5G gNodeB and UE Emulation instances. In essence, a ground terminal within the Ground Terminal domain is now accessible via 5G services, with the user plane routed through the Core Network domain, to the Transit Network domain, enabling the customer to interface with the ground terminal via a 5G network slice (or other 5G services), even when the ground terminal is using the Transit Network domain, e.g., satcom services for user plane communication.

[0053] For mobility management, user authentication is accomplished with a SIM from the MNO, representing a mobile subscription. The authentication is between the MNO and the SIM itself. It will be appreciated that SIM is being used as a generic term,

representing SIM, eSIM or other solutions for representing a 5G mobile subscription with the MNO.

[0054] The UE emulation software may run completely within the Core Network subsystem, or split between the Core Network subsystem and the ground terminal. Additionally, one embodiment uses the SIM within the cellular modem of the ground terminal for authentication while another embodiment includes a separate eSIM within the Core Network/UE Emulation subsystem, which represents the mobile subscription for one ground terminal.

[0055] The UE also maintains information regarding data sessions between the ground terminal and the MNO's network. The UE Emulation subsystem also includes information detailing the UE capabilities regarding support for various types of data session functionality that is passed to the MNO's network in messages such as Classmark messages. These messages are passed from the UE Emulation subsystem to the MNO network via the 5G gNodeB module.

[0056] The UE Emulation subsystem supports the following high-level mobility management functions, for maintaining reliable and efficient connections in 5G's complex multi-layer network. The primary mobility management functions for a UE in 5G are:

a. Registration Management

Initial Registration: When a ground terminal, as an emulated UE first connects to a 5G network, it undergoes an initial registration process. This involves authenticating the UE, establishing its identity with the network, and obtaining necessary information about its subscription and location.

Periodic Registration: The UE periodically updates the network on its location and connection status to maintain an active session.

Tracking Area Update (TAU): If the UE moves to a different tracking area (a collection of cells in the network), it performs a TAU to inform the network of its new location. This is important for maintaining seamless connectivity without the UE needing to re-register completely. This capability is supported so embodiments of this invention may support more than one 5G gNodeB.

b. Session Management

PDU Session Establishment: A Protocol Data Unit (PDU) session is a data connection that allows the UE to send and receive data over the 5G network. The session

management function establishes, modifies, and releases these sessions as the UE's connectivity needs change.

Quality of Service (QoS) Management: The UE Emulation user plane data session requires specific levels of QoS to meet latency, jitter, and other networking requirements for the ground terminal and devices connected through it via its LAN port. Additionally, the 5G network may dynamically adjust QoS parameters based on the UE's activity. This information is critical for the Core Network to manage the ground terminals and is used by the BSS subsystem.

Session Continuity Across Networks: Session management ensures that an ongoing data session remains uninterrupted as the UE moves between cells or even across different types of networks (such as 5G to LTE).

c. Location Management

Tracking and Paging: When a UE is in idle mode (not actively transmitting or receiving data), the network uses tracking area lists to keep an estimate of the UE's location. If data needs to be sent to the UE, the network initiates a paging process to locate it accurately within its current tracking area.

d. Network Slicing and Mobility Across Slices

Network Slice Selection: Network slicing allows multiple virtual networks to operate on a single physical infrastructure, each optimized for different services (e.g., IoT). The mobility management function ensures the UE connects to the correct network slice based on its application and customer requirements.

Slice-Aware Mobility: When a UE moves between cells, the network may need to adjust its connectivity across slices to maintain optimal performance and QoS. Mobility management oversees seamless transitions across network slices without disrupting active services.

e. Security and Context Management

Authentication and Key Management: As the UE moves, security credentials must be maintained to protect data and prevent unauthorized access. Mobility management includes functions for re-authenticating the UE and managing encryption keys.

Context Transfer: To reduce setup times and latency during handovers, 5G mobility management enables the transfer of UE context (such as session information, QoS settings, and security credentials) between cells or network entities. This allows for faster re-authentication and session re-establishment.

f. Idle Mode and Connected Mode Mobility

Idle Mode Mobility: Manages the UE's mobility when it is not actively engaged in data transmission, primarily through tracking area updates and paging.

Connected Mode Mobility: Manages the UE's handover and connectivity when it is actively transmitting or receiving data. This ensures seamless connectivity and high QoS, even as the UE moves across different coverage areas.

g. Policy Control and Resource Optimization

Policy Enforcement: Mobility management works with the Policy Control Function (PCF) to enforce mobility policies, such as preferred handover conditions, QoS requirements, or network access restrictions.

Load Balancing and Traffic Steering: The network dynamically allocates resources based on UE location, mobility patterns, and network load, ensuring optimal resource use and consistent QoS.

[0057] 10. Communication Hub System (CHS)

The Communication Hub System, which is a subsystem within the Core Network Domain manages the Transit Network domain resources. These resources may be at the physical layer, such as radio channels or fiber optic strands. Additionally, it manages the data link layer and the enforcement of security policies, as controlled by the Security subsystem within the OSS.

[0058] The Communication Hub is specifically designed to provide satcom services over any type of satellite, whether GEO, MEO or LEO. It maintains the satcom link(s) with the ground terminals. Traditional and non-traditional waveforms may be used. One embodiment of this invention uses traditional satcom waveforms, such as TDMA/DVB-S2x or SCPC to establish two-way, end-to-end communication between the Satcom Service hub and the remote ground terminal. Another embodiment uses specialized waveforms that behave similar to 5G waveforms, bridging the physical and datalink layers between the satcom RF and cellular RF supported by the ground terminal.

[0059] The Communication Hub also supports other physical layer communication channels, such as microwave or fiber optics.

[0060] Information is shared across the Transit Network domain and other subsystems to ensure the communication services, e.g., user and control plane channels, are in service. Additionally, this information is shared to support other network routing and

prioritization services being used by the remote ground terminal. For example, to extend 5G services, the MNO must have location information regarding the 5G user equipment (UE). This location information is sent over the Transit Network domain since this information is also shared to the MNO via the gNodeB interface enabling user plane traffic to route via cellular service directly to the ground terminal or via the Core Network domain's 5G gNodeB.

[0061] The CHC manages all satcom links, to include links to devices on the move, or otherwise referred to as COTM. Any device on the move may switch its user plane data path from the Transit Network domain to a local cellular interface. This rerouting of the user plane traffic must be coordinated with the Core Network's BSS, UE Emulation and 5G gNodeB subsystems.

[0062] The CHS consists of three subsystems, which are defined as:

a. Network Management

The Network Management subsystem manages the routing of user plane and control plane traffic to/from the Core Network and the Ground Terminal domain. Additionally, it manages the priority and QoS for each data plane. Each ground terminal has one control plane channel and one or more user plane channels. The Network Management system additionally manages the priority and bit rate and for each channel (route) and collectively the priority of all channels for all ground terminals.

The Network Management subsystem interfaces directly with the resource management subsystem to ensure resources are allocated appropriately and prioritized by the ground terminal and its user planes.

b. Resource Management

The Resource Management subsystem manages the Transit Network domain resources based on provisioned customer data within the BSS. It manages the resources to minimize congestion and to prioritize traffic during congestion events. It also manages QoS, buffering, jitter, and latency limits for user plane and control plane traffic. Resources may be assigned permanently or temporarily and changed dynamically, as controlled by the OSS.

Additionally, this subsystem interfaces with the Ground Terminal Management subsystem to assign beams, cells, and traffic routes based on the Ground Terminal location and current QoS measurements.

c. Ground Terminal Management

This subsystem manages the ground terminals by tracking their location and resource usage. It applies a set of rules for satellite beam, channel handoff, and dynamic configuration of physical layer parameters to meet required user plane data rates. The rules are defined within and enforced via software modules running within the Ground Terminal subsystem. These modules are configured/managed by the OSS subsystem.

[0063] 11. 5G gNodeB

Embodiments of the invention utilize one or more gNodeB network elements dedicated to support all the remote terminals attached to the Core Network.

[0064] There may be one or more gNodeBs dedicated to the remote terminals. In one embodiment, the MNO partner installs a gNodeB on their network and dedicates its use for implementation of the invention. Another embodiment includes the gNodeB installed within the core network and the interface to the MNO is from the gNodeB to their 5G core network domain, referenced within 5G as the N2/N3 interface. The N2/N3 interface facilitates management of the user plane data, mobility, and signaling.

[0065] The interface to the gNodeB may be implemented in multiple embodiments. For example, FAPI, which is an API standard, can be used at the PHY level, or at higher levels within the RAN stack. The use of other open sources RAN stacks, such as Gnu radio may be used for emulating UEs. The capabilities of this interface are defined within the UE Emulation subsystem.

[0066] The gNodeB interface maintains all radio and N2/N3 interfaces required by the UE Emulation subsystem to enable the ground terminals to act as a UE within the MNO network. This includes maintaining necessary traffic over the radio interface, whether emulated via an interface such as FAPI or with actual radio transmit/receive functionality.

[0067] Ground Terminal Domain

[0068] Figure 2 is a schematic of a Satellite Ground Terminal and its subsystems, according to an embodiment of the invention. The Satellite Ground Terminal is part of the Ground Terminal domain.

[0069] 1. Ethernet

This subsystem is a layer two switch. Although it is named "Ethernet", in other embodiments, it could be any data link layer switch. This is connected directly to the LAN, Cellular Modem, and SATCOM Modem subsystems.

[0070] 2. LAN

This subsystem provides networking services for the end devices using the ground terminal and Core Network for user plane data services. It serves as the primary interface for connecting the IOT end devices to the ground terminal, enabling each device to access the cellular and Transit Domain network services for data communications.

The LAN subsystem essentially acts as a bridge between the IOT devices, which connects to the cellular or Transit Network domain networks.

Purpose and Functions of a LAN Port on a SATCOM Modem include:

a - Enabling Device Connectivity:

The LAN port allows the local devices to connect directly to the Transit Domain and/or cellular network, providing them with data communication to the customer.

b - Providing Reliable Data Transfer within a Local Network:

The LAN port enables reliable data transfer between the Transit Network Domain/cellular network for connected local devices, typically through an Ethernet cable or Wifi.

This allows for uninterrupted data flow for each device.

c - Enabling IP Address Assignment and Network Management:

Through the LAN port, the ground terminal can assign IP addresses to connected devices via DHCP (Dynamic Host Configuration Protocol), enabling each device to communicate over the network with unique addressing.

This function supports network management activities like monitoring, traffic prioritization, and troubleshooting, ensuring efficient use of the satellite link.

d - Facilitating Secure Network Connections:

The LAN port can connect the ground terminal to devices that handle secure communication, such as VPN routers or firewalls, allowing encrypted and secure data transmission over the Transit Network domain and/or cellular network.

[0071] 3. SATCOM Modem

This subsystem is a modem that connects to a satellite system, which is part of the Transit Network domain, to transmit and receive data. It converts digital data from the LAN subsystem into a signal format that can be transmitted over satellite frequencies. It also converts incoming satellite signals back into digital data to be passed to the LAN subsystem.

The SATCOM subsystem is connected to the Ethernet subsystem.

[0072] 4. Cellular Modem

The cellular modem subsystem connects to a 5G cellular network to provide data connectivity. It enables the SATCOM Ground Terminal to send and receive data directly over a cellular connection. This cellular data connection operates in parallel to the UE Emulation subsystem's data service. In essence, the ground terminal appears as two UEs, each operating independently of each other. One is controlled by the UE Emulation subsystem within the Core Network domain while the other is controlled by the ground terminal within the Ground Terminal domain.

The Cellular Modem comprises:

- a. **Network Access:** A SIM card can access a mobile carrier's network, enabling the Ground Terminal to establish a link over the cellular infrastructure.
- b. **Modulation and Demodulation:** Similar to the SATCOM modem, the cellular modem modulates outgoing data to an RF signal that the cellular network can transmit. It also demodulates incoming signals back into digital data that devices can use.
- c. **Mobility Management:** The Cellular Modem's cellular subscription is managed by the local cellular network.

[0073] 5. UDC

This subsystem is the up and down converter, which are components of the SATCOM link, responsible for converting signals between different frequency.

a. **Upconverter**

An upconverter is used to increase the frequency of a signal so it can be transmitted over the satellite link, which in a typical embodiment is Ku- and Ka band.

The upconverter takes the low-frequency signal generated by the modem (typically in the L-band, around 950–1450 MHz) and converts it to a much higher frequency (usually in the C, Ku, or Ka bands, depending on the satellite system in use by the Transit Network domain).

b. Downconverter

A downconverter does the reverse: it reduces the frequency of a received signal so that the SATCOM Modem can process it.

After the satellite receives the signal and transmits it back down to Earth, the ground terminal's ESA receives it at a high frequency. The downconverter shifts this high-frequency signal down to a lower, more manageable frequency (typically back to the L-band).

[0074] 6. Central Processing Unit (CPU)

The Central Processing Unit subsystem is a general purpose computing device running software within the ground terminal. The software's role is to:

- 1.) Manage all RF resources
- 2.) Manage cellular service
- 3.) Manage layer 3 (L3) routing between the SATCOM link and the cellular network
- 4.) Provide configuration management, fault management, accounting, performance management, and security services
- 5.) Communicate with the Core Network domain subsystems.

Additionally, the CPU includes an operating system, such as Linux, along with various software tools and utilities to aid in support and management of the ground terminal.

Figure 4 shows a schematic diagram of an exemplary computing device that may be used to realise the CPU. Further details on Figure 4 and the computing device will be provided below.

[0075] 7. GNSS (Global Navigation Satellite System)

The GNSS subsystem is used to help accurately align and peak the antenna, which in one embodiment is an electronically steerable antenna (ESA) by providing precise location and orientation information. For the Ground Terminal subsystem, precise antenna alignment is desirable to ensure the strongest possible signal for establishing and maintaining the SATCOM link.

[0076] The following steps take place:

- 1.) The Satellite Ground Terminal determines its exact location:

The GNSS subsystem provides the exact geographic location (latitude, longitude, and altitude) of the Ground Terminal's location on Earth.

This location information is necessary to calculate the azimuth (horizontal angle) and elevation (vertical angle) required to align with a specific satellite in geostationary orbit.

2.) Satellite Selection and Calculation:

Using the satellite's known position in orbit, the subsystem calculates the necessary azimuth and elevation angles based on the GNSS-determined location.

This calculation tells the ESA which direction to point horizontally and how high above the horizon to aim.

3.) Initial Alignment:

The ESA electronically steers its beam position according to the calculated azimuth and elevation angles.

4.) Signal Peaking and Fine Adjustment:

Once the ESA's beam is pointed roughly in the right direction, software running within the CPU optimizes or "peaks" the alignment by adjusting the ESA's beam in small increments.

The goal is to maximize the received signal strength and quality, measured in metrics like Signal-to-Noise Ratio (SNR) or Effective Isotropic Radiated Power (EIRP).

5.) Locking onto the Signal:

After peaking, the ESA's beam is locked in position to maintain a stable connection with the satellite. This stability is critical for reliable data transmission.

[0077] The Benefits of Using GNSS for the ESA beam alignment are:

Speed and Precision: GNSS data simplifies alignment by providing exact location coordinates, which accelerates the alignment process and improves accuracy.

Automated Positioning: In situations where the Satellite Ground Terminal is moving, such as on a vehicle or ship, the GNSS enables automatic, real-time adjustments to maintain the satellite connection.

Reliable Connectivity: The properly peaked ESA ensures optimal signal quality, reducing potential interruptions and improving overall data throughput.

The GNSS also supports an out-of-band communication channel that is used by the Core Network Domain subsystems to manage the Satellite Ground Terminal when the Ground Terminal cannot establish a SATCOM link or communication via the cellular network.

[0078] Interfaces

Referring to Figure 1, there are a plurality of interfaces between the various subsystems, components and domains, namely: (1) 5G interface, (2) Customer interface, (3) User Plane interface, (4) Control Plane interface, (5) Device interface, and (6) Web interface.

[0079] (1) 5G interface

The Core Network domain interface to the 5G network uses FAPI (functional application platform interface) or direct N2/N3 services to the cellular core network. This provides an API at the PHY level. The core network runs UE emulation software. A virtual UE instance for each remote terminal is created and managed by the UE Emulation subsystem. The UE emulation software provides mobility management services and communicates over the transit network to the remote terminal. Either an eSIM is managed by the UE Emulation subsystem or the remote terminal has an API for SIM services, specifically authentication.

The mobile operator installs a dedicated gNodeB on their network that the Core Network domain interfaces with using FAPI. Another embodiment is for the Core Network domain to directly interface to the cellular core network via the N2/N3 interface.

Regardless of the interface type to the 5G network, all Satellite Ground Terminals appear as UEs attached to the cellular core network through a gNodeB. As described above, one embodiment is for the Core Network domain to use the FAPI interface at the PHY level to emulate UEs for each Satellite Ground Terminal.

Devices on the LAN interface of the ground terminal appear as different devices connected through the UE (ground terminal) to the MNO's network, similar to a personal hotspot.

The Satellite Ground Terminal also has a cellular data connection directly with the local 5G network using its Cellular Modem subsystem. The Satellite Ground Terminal routes user plane traffic over the local cellular network using the integrated SIM when it is available and prioritized as the preferred route.

When the local cellular network is not available, or set to a lower priority route than the Transit Network domain, the Core Network and Satellite Ground Terminal routes and receives User Plane traffic to/from the 5G interface between the Core Networks domain's UE Emulation and 5G gNodeB subsystems.

[0080] (2) Customer Interface

The customer interface is the collection, or totality, of the User Plane (3), Control Plane (4), and web interface (6) interfaces enabling the customer to control, process, and manage the extending of 5G services to the remote devices. The customer interface may utilize any types of network services for communication, such as cloud-based services, VPNs, or packet switched networks.

[0081] (3) User Plane and (4) Control Plane Interfaces

User plane data refers to the data being transmitted between end devices and the customer network, which interfaces via the 5G gNodeB, Cellular Modem and Customer Portal subsystems.

In contrast, control plane data manages the signalling and control functions of the network. In simpler terms, user plane data is the content of the communication, such as sensor data sent over the Transit Network and/or Cellular Network.

The routing and management of user and control plane data are described below.

[0082] Routing

The core network receives user plane data from the ground terminal from one or more transit networks, such as cellular, satcom or microwave. These different streams of user plane data are aggregated together and routed through the billing subsystem. Additional subsystems for performance management, configuration management, accounting and performance management perform the typical FCAPs services.

Out of band communication to the ground terminal is via the GNSS subsystem. This is used for troubleshooting and management of the ground terminal.

a. Control Plane

The control plane data is routed to/from the core network to the remote ground terminals via in-band and out-of-band messaging. In band routes are via satellite, cellular or any other physical layer access to the remote site, such as fiber or microwave.

Out of band control plane traffic is routed via GNSS. Small messages are used to check the health and status of the Ground Terminal subsystems, such as the ESA and cellular modem. The ESA can be managed and controlled via control plane messages over the GNSS. Examples of control messages are:

1. TLE (two-line element) messages instructing the ESA to point towards an orbital slot

2. Changes to BW, center frequency, mod/cod, FEC, and other configuration parameters required to transmit and receive on carriers over satellite

3. Health and status messages to obtain performance management, configuration management, accounting and fault management information from the ground terminal and its subsystems.

Besides GNSS, other out-of-band communication solutions may be used, such as SMS, WiFi, or L2 circuits.

b. User Plane

User plane traffic is routed over satellite, over cellular, or other physical layer access to the remote site, such as fiber or microwave.

Least cost routing capabilities are integrated into the Satellite Ground Terminal and the Core Network. The Core Network controls the routing tables, weights, and algorithms for both the user plane and control plane data.

Routing of user plane traffic at the core network is as follows:

Received from the remote ground terminal: As user plane traffic is received from the Satellite Ground Terminal, the Core Network determines which customer the traffic is assigned to. This is accomplished by determining the traffic origination addresses, whether by IP address, ground terminal ID, tunnel IDs when GTP is used between the ground terminal and the core network, or other means.

The core network applies performance management and accounting algorithms to the traffic to support billing and an operational support system. The traffic is then either routed directly to the end customer via Internet, L2 circuit, a web service, APIs, tunnels or similar path. Additionally, the traffic may be routed to the gNodeB subsystem and into the partner MNO's network. In this scenario, the traffic is routed to the MNO so the traffic from the remote ground terminal is treated as any other 5G user plane data for the customer, and therefore is routed to a network slice or some other 5G service the customer has in place with the MNO. It is worth noting that the latter scenario is an extension of the MNO's 5G network over the transit network, making all devices connected to the ground terminal treated as devices on the MNO's 5G network.

Transmitted (routed) to the remote ground terminal: For user plane traffic destined to the Satellite Ground Terminal and devices connected to the ground terminal via its LAN interface, it is routed via the user plane routes supported by the Core Network, which

includes satellite and cellular routes. Other routes may be available such as microwave, fiber, or Internet. The Transit Network domain is used to transport this traffic.

The user plane traffic to be sent to the Satellite Ground Terminal is first received by the Core Network through the customer interfaces, which are directly connected routes to the customer via L2 circuits, VPNs, web services, or APIs. Traffic can also be received via the gNodeB interface. In this scenario, the user plane traffic was generated initially by a 5G device or an external interface into the partner MNO's 5G network.

Additionally, information regarding the control and user plane traffic is made available to the customer via the Web Interface. This information includes FCAPS information regarding both user and control plane traffic flows, user access, deep packet inspection (DPI), billing, and service availability.

[0083] (5) Device Interface

This is the interface between the end devices and the LAN subsystem within the Satellite Ground Terminal. This interface is the end devices' user plane data traffic, requiring communication to/from the customer. This interface supports any physical, data link and network layer architecture of the end devices. Examples include LoRa, Ethernet and Wifi. These three physical layer and data link layer access types provide a range of connectivity. It will be appreciated that implementations of the invention are not limited to these three examples.

[0084] (6) Web Interface

The Web interface is both a web-based interface and a messaging-based interface. The customer accesses the system via a web interface to an HTTPS portal.

The Web interface is the user interface for the end customer. It provides access to manage the customer's network of ground terminals and devices connected on the LAN interface of the Satellite Ground Terminal(s). The Web interface allows for the provisioning of services, the management of data service, to include managing user plane traffic, routing of the traffic, and various DPI capabilities.

The Web interface offers the end user access to their accounts, data services, helpdesk, and information relevant to their interactions with embodiments of the invention.

Details on the key elements of the Web Interface are as follows:

1. Dashboard

The dashboard is a personalized landing page after login with a snapshot of the most relevant information, such as account status, recent activity, usage, and notifications. The dashboard includes an interactive notification center showing alerts about payments due, product updates, or support tickets.

2. Navigation Menu

This menu provides a clear and responsive navigation menu, typically on the left sidebar or as a top menu with dropdowns. Key sections include:

Account Overview: Details about user information, subscription attributes, billing, and preferences.

Services: History and status of the system's services and access to licensed services.

Support: Options to access FAQs, open support tickets, live chat, and knowledge base articles.

Billing and Payments: Payment history, upcoming invoices, stored payment methods, and options to update billing details.

Reports and Analytics: This includes access to reports and analytics related to each domain, which is collected and stored by the Performance Management subsystem.

Settings: Controls for user preferences, privacy settings, security (e.g., password changes), and notification preferences.

3. Account Management

Profile Settings: Users can view and update their personal information, such as contact details, language preferences, and notification settings.

Subscription/Plan Details: Displays the current plan or subscription level, with options to upgrade or downgrade, view plan benefits, and manage add-ons.

Payment and Invoices: A section to view and download past invoices, update payment methods, and set up automatic payments.

Service History: Displays service orders, licensed services and historical data, such as order numbers.

4. Support and Help Center

FAQs and Knowledge Base: A searchable section for articles, tutorials, and guides on frequently asked questions and common issues.

Support Tickets: Allows customers to create and track support tickets, with real-time status updates and a history of all interactions.

Live Chat/Chatbot: A chat function for instant support or, alternatively, a chatbot to answer basic queries and direct users to relevant resources.

5. Data and Analytics

Usage Statistics: Interactive graphs or charts showing the customer's usage of the services over time.

Reports: Downloadable or viewable reports with metrics such as data usage, transaction history, or service performance.

Trends and Insights: Data-driven insights that help customers understand patterns and optimize their use of the service.

6. Notification and Alerts Center

Notifications: Displays alerts related to upcoming payments, expiring subscriptions, new support responses, and system updates.

Alert Customization: Allows customers to customize what types of notifications they want to receive (e.g., email, SMS, or push notifications).

Fault management: Displays active faults, allows for silencing faults and also clearing faults.

7. Security and Privacy Settings

Security Controls: Options to enable two-factor authentication, set up password recovery options, and view recent login activity.

Privacy Settings: Controls for data sharing preferences, cookie settings, and how data is used by the customer.

8. Cellular and Transit Network Service

Status: Status of user and control plane data uptime, throughput and error counts.

The Customer interface also includes the user plane traffic originating/terminating with the end-user. The user plane data may use Internet, L2 circuit, a web service, APIs, tunnels or similar path across this interface.

[0085] Figure 3 shows a flow diagram illustrating an exemplary method 300 of extending 5G service to a remote ground terminal, in accordance with an embodiment.

[0086] Step 302 involves establishing an interface between an existing 5G cellular network and a core network. A gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network. The interface may be a Functional Application Platform Interface (FAP) interface or a N2/N3 interface.

[0087] Step 304 involves executing a UE emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal. In the case of a FAPI interface, the FAPI interface is used at the PHY level to emulate the UE.

[0088] Step 306 involves establishing end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network. The transit network comprises at least one of the following communication channels: satellite, fiber, and microwave.

[0089] Routing path A: The method 300 may further include the step of routing user plane traffic between the remote ground terminal and the core network via the transit network and the gNodeB.

[0090] Routing path B: The method 300 may further include the steps of: establishing a cellular data connection directly between the remote ground terminal and the existing 5G cellular network using a cellular modem module of the remote ground terminal; and routing user plane traffic between the remote ground terminal and the core network over the existing 5G cellular network, bypassing the gNodeB.

[0091] The above described Routing paths A and B may be implemented as alternatives, i.e. path A or path B only.

[0092] Routing paths A and B may also be implemented to run concurrently, i.e. at the same time for a particular UE. This is because the cellular modem within the Satellite Ground Terminal and the UE emulation subsystem within the Core Network appear to the 5G network as two separate, independent devices, User Equipment (UE).

[0093] The method 300 may further include the steps of: obtaining location information associated with the remote ground terminal; and transmitting the location information via the transit network and the gNodeB.

[0094] Figure 4 shows a schematic diagram of a system 400 for extending 5G service to a remote ground terminal, in accordance with an embodiment. The system 400 includes an interface module 402 that is configured to establish an interface between an existing 5G cellular network and a core network. A gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network. The interface may be a Functional Application Platform Interface (FAPI) interface or a N2/N3 interface.

[0095] The system 400 also includes an emulation module 404 that is configured to execute a UE emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal. In the case of a FAPI interface, the FAPI interface is used at the PHY level to emulate the UE.

[0096] The system 400 also includes a communication module 406 that is configured to establish end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network. The transit network comprises at least one of the following communication channels: satellite, fiber, and microwave.

[0097] The communication module may be further configured to route user plane traffic between the remote ground terminal and the core network via the transit network and the gNodeB. Alternatively or in addition, the communication module may be further configured to: (i) establish a cellular data connection directly between the remote ground terminal and the existing 5G cellular network using a cellular modem module of the remote ground terminal; and (ii) route user plane traffic between the remote ground terminal and the core network over the existing 5G cellular network, bypassing the gNodeB.

[0098] Figure 5 shows a schematic diagram of an exemplary computing device 500 (hereinafter interchangeably referred to as a computer system) used to realise a system for extending 5G service to a remote ground terminal, in accordance with an embodiment. The following description of the computing device 500 is provided by way of example only and is not intended to be limiting.

[0099] As shown in Figure 5, the example computing device 500 includes a processor 504 for executing software routines. Although a single processor is shown for the sake of clarity, the computing device 500 may also include a multi-processor system. The processor 504 is connected to a communication infrastructure 506 for communication with other components of the computing device 500. The communication infrastructure 506 may include, for example, a communications bus, cross-bar, or network.

[00100] The computing device 500 further includes a main memory 508, such as a random access memory (RAM), and a secondary memory 510. The secondary memory 510 may include, for example, a hard disk drive 512 and/or a removable storage drive

514, which may include a magnetic tape drive, an optical disk drive, or the like. The removable storage drive 514 reads from and/or writes to a removable storage medium 518 in a well-known manner. The removable storage medium 518 may include a magnetic tape, optical disk, or the like, which is read by and written to by removable storage drive 514. As will be appreciated by persons skilled in the relevant art(s), the removable storage unit 518 includes a computer readable storage medium having stored therein computer executable program code instructions and/or data.

[00101] In an alternative embodiment, the secondary memory 510 may additionally or alternatively include other similar devices for allowing computer programs or other instructions to be loaded into the computing device 500. Such devices can include, for example, a removable storage unit 522 and an interface 520. Examples of a removable storage unit 522 and interface 520 include a removable memory chip (such as an EPROM or PROM) and associated socket, and other removable storage units 522 and interfaces 520 which allow software and data to be transferred from the removable storage unit 522 to the computer system 500.

[00102] The computing device 500 also includes at least one communication interface 524. The communication interface 524 allows software and data to be transferred between computing device 500 and external devices via a communication path 526. In various embodiments, the communication interface 524 permits data to be transferred between the computing device 500 and a data communication network, such as a public data or private data communication network. The communication interface 524 may be used to exchange data between different computing devices 500 which such computing devices 500 form part an interconnected computer network. Examples of a communication interface 524 can include a modem, a network interface (such as an Ethernet card), a communication port, an antenna with associated circuitry and the like. The communication interface 524 may be wired or may be wireless. Software and data transferred via the communication interface 524 are in the form of signals which can be electronic, electromagnetic, optical or other signals capable of being received by communication interface 524. These signals are provided to the communication interface via the communication path 526.

[00103] Optionally, the computing device 500 further includes a display interface 502 which performs operations for rendering images to an associated display 530 and an audio interface 532 for performing operations for playing audio content via associated speaker(s) 534.

[00104] As used herein, the term "computer program product" may refer, in part, to removable storage medium 518, removable storage unit 522, a hard disk installed in hard disk drive 512, or a carrier wave carrying software over communication path 526 (wireless link or cable) to communication interface 524. Computer readable storage media refers to any non-transitory tangible storage medium that provides recorded instructions and/or data to the computing device 500 for execution and/or processing. Examples of such storage media include floppy disks, magnetic tape, CD-ROM, DVD, Blu-ray™ Disc, a hard disk drive, a ROM or integrated circuit, USB memory, a magneto-optical disk, or a computer readable card such as a PCMCIA card and the like, whether or not such devices are internal or external of the computing device 500. Examples of transitory or non-tangible computer readable transmission media that may also participate in the provision of software, application programs, instructions and/or data to the computing device 500 include radio or infra-red transmission channels as well as a network connection to another computer or networked device, and the Internet or Intranets including e-mail transmissions and information recorded on Websites and the like.

[00105] The computer programs (also called computer program code) are stored in main memory 508 and/or secondary memory 510. Computer programs can also be received via the communication interface 524. Such computer programs, when executed, enable the computing device 500 to perform one or more features of embodiments discussed herein. In various embodiments, the computer programs, when executed, enable the processor 504 to perform features of the above-described embodiments. Accordingly, such computer programs represent controllers of the computer system 500.

[00106] Software may be stored in a computer program product and loaded into the computing device 500 using the removable storage drive 514, the hard disk drive 512, or the interface 520. Alternatively, the computer program product may be downloaded to the computer system 500 over the communications path 526. The software, when executed by the processor 504, causes the computing device 500 to perform functions of embodiments described herein.

[00107] It is to be understood that the embodiment of Figure 5 is presented merely by way of example. Therefore, in some embodiments one or more features of the computing device 500 may be omitted. Also, in some embodiments, one or more features of the computing device 500 may be combined together. Additionally, in some embodiments,

one or more features of the computing device 500 may be split into one or more component parts.

[00108] It will be appreciated that the elements illustrated in Figure 5 function to provide means for performing the various functions and operations as described in the above embodiments.

[00109] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A method of extending 5G service to a remote ground terminal, comprising:
 - establishing an interface between an existing 5G cellular network and a core network, wherein a gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network;
 - executing a UE emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal; and
 - establishing end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network.
2. The method of claim 1, wherein the interface is a Functional Application Platform Interface (FAPI) interface or a N2/N3 interface.
3. The method of claim 2, wherein the FAPI interface is used at the PHY level to emulate the UE.
4. The method of claim 1, further comprising:
 - routing user plane traffic between the remote ground terminal and the core network via the transit network and the gNodeB.
5. The method of claim 1, further comprising:
 - establishing a cellular data connection directly between the remote ground terminal and the existing 5G cellular network using a cellular modem module of the remote ground terminal; and
 - routing user plane traffic between the remote ground terminal and the core network over the existing 5G cellular network, bypassing the gNodeB.
6. The method of claim 1, further comprising:
 - obtaining location information associated with the remote ground terminal; and
 - transmitting the location information via the transit network and the gNodeB.
7. The method of claim 1, wherein the transit network comprises at least one of the following communication channels: satellite, fiber, and microwave.

8. A system for extending 5G service to a remote ground terminal, comprising:
- an interface module configured to establish an interface between an existing 5G cellular network and a core network, wherein a gNodeB (5G base station) is installed on the existing 5G cellular network or within the core network;
 - an emulation module configured to execute a UE emulation process on the core network to create a virtual user equipment (UE) instance for the remote ground terminal; and
 - a communication module configured to establish end-to-end communication between the remote ground terminal and the gNodeB via a transit network, such that the remote ground terminal appears as a 5G UE attached to the existing 5G cellular network.
9. The system of claim 8, wherein the interface is a Functional Application Platform Interface (FAP) interface or a N2/N3 interface.
10. The system of claim 9, wherein the FAP interface is used at the PHY level to emulate the UE.
11. The system of claim 8, wherein the communication module is further configured to route user plane traffic between the remote ground terminal and the core network via the transit network and the gNodeB.
12. The system of claim 8, wherein the communication module is further configured to:
- establish a cellular data connection directly between the remote ground terminal and the existing 5G cellular network using a cellular modem module of the remote ground terminal; and
 - route user plane traffic between the remote ground terminal and the core network over the existing 5G cellular network, bypassing the gNodeB.
13. The system of claim 8, wherein the transit network comprises at least one of the following communication channels: satellite, fiber, and microwave.