White paper
Cisco public

Non-Terrestrial Networks: Preparing for the Emerging Direct-to-Device Satellite Market Transformation

Partnering with Cisco for Success

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Introduction

The emergence of Direct-to-Device (D2D) satellite connectivity, standardized through 3GPP specifications, represents a paradigm shift in global telecommunications. By enabling standard smartphones to communicate directly with satellite networks without specialized hardware, this technology creates unprecedented opportunities for both Satellite Network Operators (SNOs) and Mobile Network Operators (MNOs) to deliver truly ubiquitous connectivity across previously unreachable regions of the planet.

Historically, satellite-based communication has been limited by proprietary technology requiring bulky, expensive custom devices and services priced beyond the reach of most consumers. However, 3GPP Release 17 is changing this landscape by introducing standards-based connectivity for direct communication between satellite-based radio networks and everyday smartphones and devices. This innovation not only complements terrestrial network connectivity but extends coverage to areas previously unreachable by traditional networks, bringing vital connectivity to unserved populations and creating significant social and economic benefits.

These standardization efforts include adapting 5G New Radio (NR), Narrowband IoT (NB-IoT), and LTE for machine-type communications (LTE-M) to operate via satellite. This technology framework, known as Non-Terrestrial Networks (NTNs), enables services variously described as "supplemental coverage from space," "direct-to-device," or "direct-to-cell" connectivity.

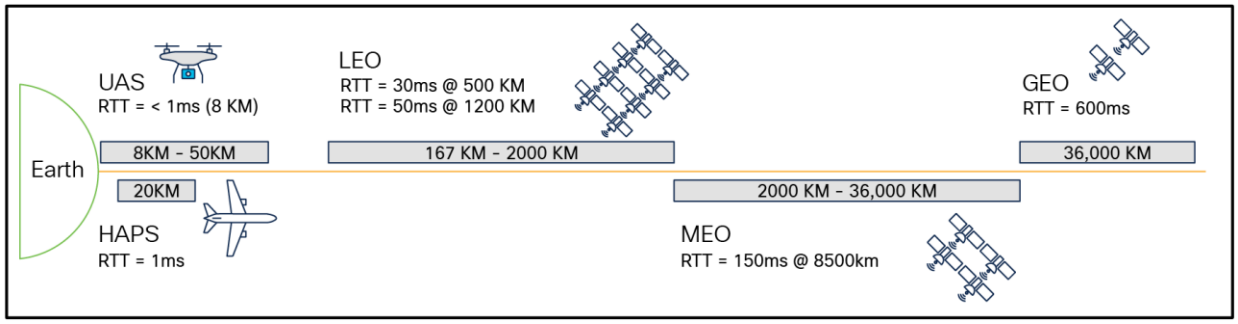

Figure 1.
Non-terrestrial network types

Understanding Non-Terrestrial Networks

Non-Terrestrial Networks (NTNs) encompass network segments that utilize space-borne or airborne vehicles for transmission:

- **Space-borne vehicles (satellites):** Including both Geosynchronous (GSO) and Non-Geosynchronous (NGSO) orbiting satellites. NGSO satellites operate in Low Earth Orbit (LEO) at altitudes between 300-1500 km, or Medium Earth Orbit (MEO) at approximately 7,000-25,000 km.
- **Airborne vehicles:** High-Altitude Platforms (HAPs) including Unmanned Aircraft Systems (UAS), both Lighter-Than-Air (LTA) and Heavier-Than-Air (HTA), deployed at altitudes between 8-50 km.

Current D2D Implementation Approaches

Direct-to-device satellite services have emerged in several implementation forms:

- **Proprietary technology solutions:** Exemplified by Apple's collaboration with Globalstar, using proprietary technology and spectrum previously allocated for legacy satellite services.
- **Pre-3GPP Release 17 implementations:** These solutions aim to enable existing smartphones, without hardware modifications, to access cellular coverage from space using spectrum leased from mobile network operators (with regulatory approval). Examples include Starlink's service using T-Mobile spectrum and AST Space Mobile's offerings via AT&T/Verizon spectrum. In these implementations, the satellite network's cellular infrastructure handles complex Doppler and timing adjustments.
- **3GPP Release 17/18/19 standards-based solutions:** This emerging segment requires devices to support NTN-specific spectrum for NB-IoT and 5G NR services. Release 17 NTN NB-IoT networks have already been deployed by some providers working with MNOs, such as Skylo using legacy satellite provider spectrum to provide NB-IoT services for basic messaging, SOS functions, and IoT connectivity for operators like Verizon.

Focus of this paper

This white paper focuses specifically on **3GPP Release 17/18 standards-based direct-to-device service offerings using LEO-based NTNs**. These services primarily utilize the L band (1.6 GHz spectrum, n253–n255) and S band (2 GHz spectrum, n256) designated for NTN usage, with Ka+Ku band (n510–n512) under consideration for future NTN applications.

Total addressable market for direct-to-device services

The advent of Direct-to-Device (D2D) satellite technology is revolutionizing connectivity, offering Satellite Network Operators (SNOs) and Mobile Network Operators (MNOs) unprecedented opportunities to enhance global coverage, reduce latency, and drive innovation in the telecommunications landscape.

According to GSMA, LEO satellite connectivity presents a multibillion-dollar total addressable market (TAM) across consumer and enterprise segments. Service providers and satellite connectivity providers are best positioned to capture the consumer TAM. The enterprise and B2B TAM include connections that will be net new and existing connections that will add satellite connectivity for redundancy and backup. Satellite network operators are expected to provide wholesale roaming connectivity for service provider network customers, as they own end customer relationships.

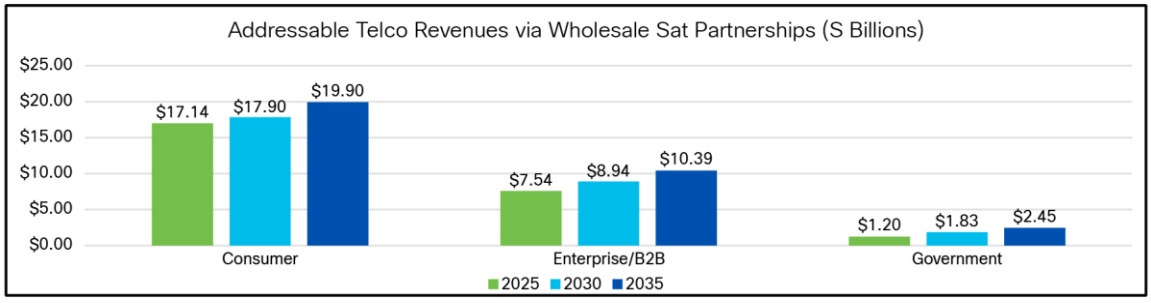

Figure 2.
Non-terrestrial network TAM (Source GSMA)

Non-terrestrial network use cases

Figure 3.
Non-terrestrial network industrial use cases

While the majority of the revenue is expected to be derived from the consumer use case segment, the enterprise and B2B use cases shown above are expected to leverage NTN connectivity with supplemental coverage from space, along with terrestrial connectivity where applicable. Smart network selection intelligence applets embedded in user SIMs/eSIMs can be further programmed to select terrestrial and non-terrestrial networks based on various attributes, including signal strength, quality, business rules, etc., to provide seamless connectivity to end user devices.

Non-terrestrial network architectural/general aspects

In Release 17, only direct access with a transparent satellite is considered. Basic assumptions are that User Equipment (UE) is equipped with GNSS, and transparent mode satellites (LEO/MEO/GEO) are relaying the Uu interface only at the physical layer level. In this architecture, a 5G NR signal from the base station (gNB) is sent to a satellite via the ground station using the feeder link and is transmitted from the satellite Radio Access Network (RAN) to user devices on earth via the service link.

In the transparent satellite architecture, the base station (gNB) relays the Uu interface toward the satellite. The satellite transparently relays the signal to the user on the ground. In other words, the satellite acts as a repeater. The only processing that can be performed on the satellite is radio frequency processing such as frequency conversion, amplification, and beam management.

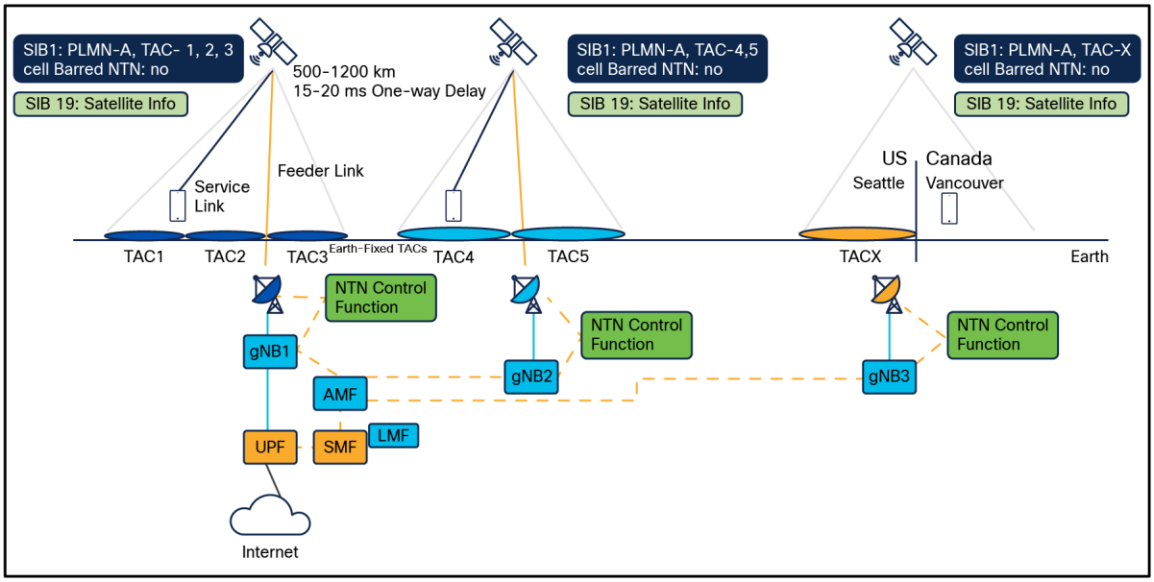

Figure 4.
Non-terrestrial network Release17 transparent satellite

Figure 4 shows the most typical deployment architecture of a service transmitting directly from a satellite to a device. In this example, a LEO satellite is the preferred choice due to its lower latency compared to MEO/GEO and better commercial viability.

As illustrated in the figure, a ground-based eNB/gNB transmits the 5G NR air interface signal to the satellite gateway. The signal is then transmitted from the ground station to the LEO satellite via the feeder link.

The LEO satellite uses a transparent NTN payload. The satellite radio antenna, which is also referred to as the satellite payload or NTN payload, captures the signal and retransmits it back down to Earth via the service link of the satellite, covering a wide area on Earth subject to the altitude of operation, properties, and capabilities of the satellite radio antenna

The UE receives the signal from the satellite via the service link. Similarly, when the UE transmits the signal, it reaches the satellite via the service link, and the satellite payload then relays the signal to the ground station via the feeder link. The ground station sends the signal back to the gNB.

A typical LEO satellite at an operating altitude of 500 km travels at the speed of 8 km per second and completes one orbital journey in 90 minutes (about 1 and a half hours), while a satellite at an altitude of 1000 km travels at the speed of 7.6 km per second and takes 120 minutes (about 2 hours) to complete one orbital journey. Considering a typical LEO satellite NTN cell size of 40 to 50 square kilometers, a typical LEO satellite cell could expect the serving satellite to change every 5 to 10 minutes as it moves out of one cell and into another and would need to support seamless handover to ensure uninterrupted connectivity. A robust mechanism is needed on the NTN gateway for mapping ground-based cells with the current serving satellite's eNB/gNB air interface signal mapping and coordination work for a physical land geographical cell to a moving satellite-based cell in NTN. This is done by the NTN control function. The NTN control function plays a central role in mapping ground-based cells to satellite cells. It leverages satellite ephemeris data, geolocation information, and sophisticated algorithms to ensure accurate and real-time mapping. The NTN control function, along with updated functionalities in gNB/AMF and the UE, ensures the integrity of the solution. From an architectural perspective, while the net new component of the solution is the satellite-based RAN and NTN control function, the overall solution must be simple, scaled, and programmable for easier consumption while addressing key enablers for NTN business success.

Non-terrestrial network business success drivers

As previously mentioned, NTN direct-to-device services are deployed in various configurations: Proprietary technology (the Apple-Globalstar solution), 3GPP-compliant services that include Pre-Release 17 (the ones that use the LTE spectrum of the operator and provide services to the end users of regular smartphones, such as AST Space Mobile, Starlink, etc.), and those services with Release 17 and beyond, which are designated to operate with mobile satellite services spectrum and need NTN Release 17-compliant UE (such as Skylo NTN-NB-IoT, etc.).

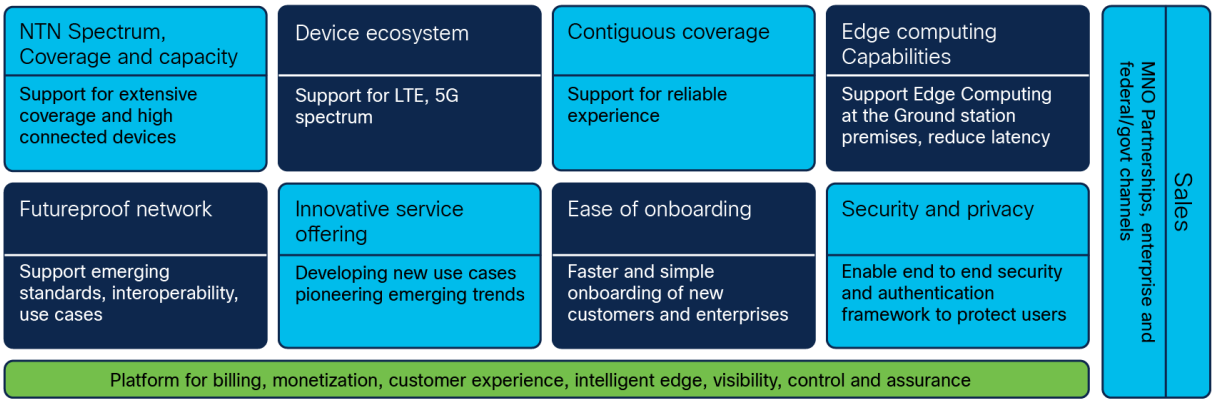

Figure 5.
Key NTN business success drivers

The key factors that determine the success of NTN direct-to-device service offerings are listed in the figure above.

Cisco Mobility Services Platform for NTN

As part of Cisco's broader NTN solution portfolio, we offer the Mobility Services Platform to Satellite Network Operators (SNOs) and Mobile Network Operators (MNOs), enabling them to integrate with an open ecosystem and provide a range of value-added services.Starting with low data messaging (NB-IoT), followed by voice and then 5G NR, this Software-as-a-Service (SaaS) model leverages proven Cisco® technologies like IoT Control Center, Packet Core, and APIs to reduce complexity while accelerating time to market and business value for targeted use cases through simplified integration. The platform offers ready-made and customizable templates to instantly activate services. It provides a unified API that abstracts away complex, disparate technologies, streamlining network configuration, service activation, and subscriber and SIM management. Preintegrated, enterprise-ready value-added services from Cisco allow communication service providers to immediately launch and monetize services.

Cisco Mobility Services Platform for NTN includes:

- LTE/5G converged core solution
- Phased support for messaging service and voice
- A global roaming interconnect for service delivery
- A single platform for enterprises to interact
- APIs and satellite-specific vertical integration (ports, connected vehicles)
- Built in End-to-end assured connectivity in Cisco Packet Core
- Proactive assurance for Critical KPI's-Latency, Packet Loss, Jitter
- Ability to provide unified visibility portal to Service Providers
- Achieving full eSIM potential with eSIM orchestration across all networks

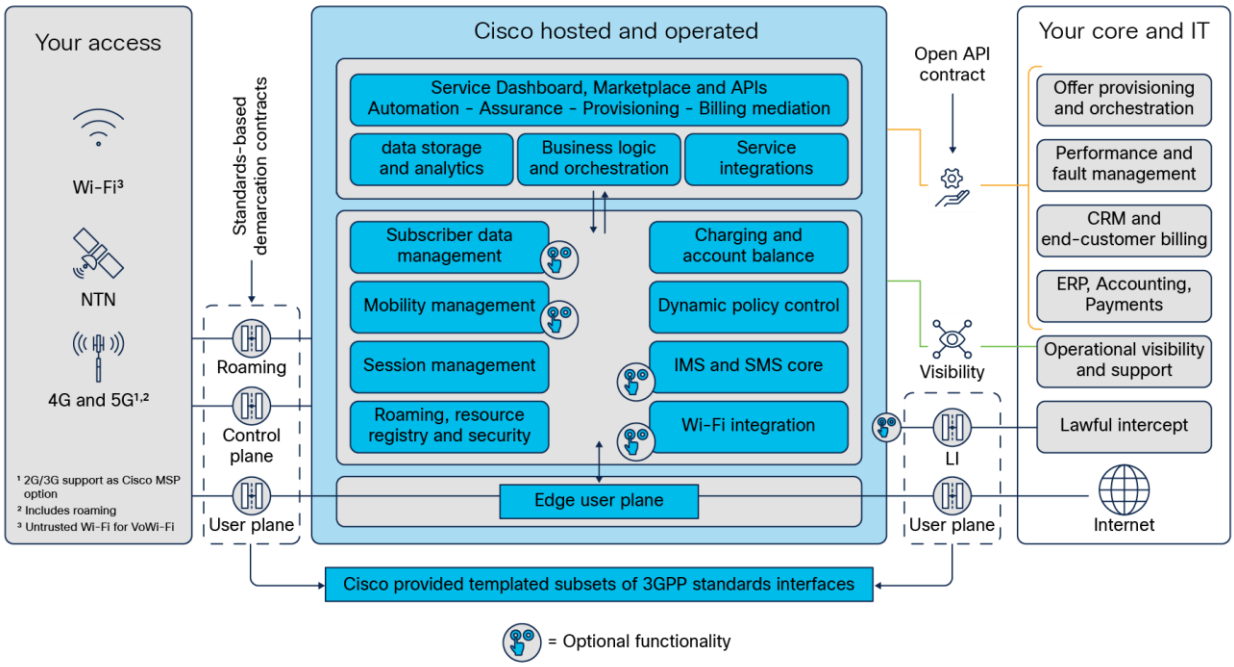

Figure 6.
Cisco Mobility Services Platform

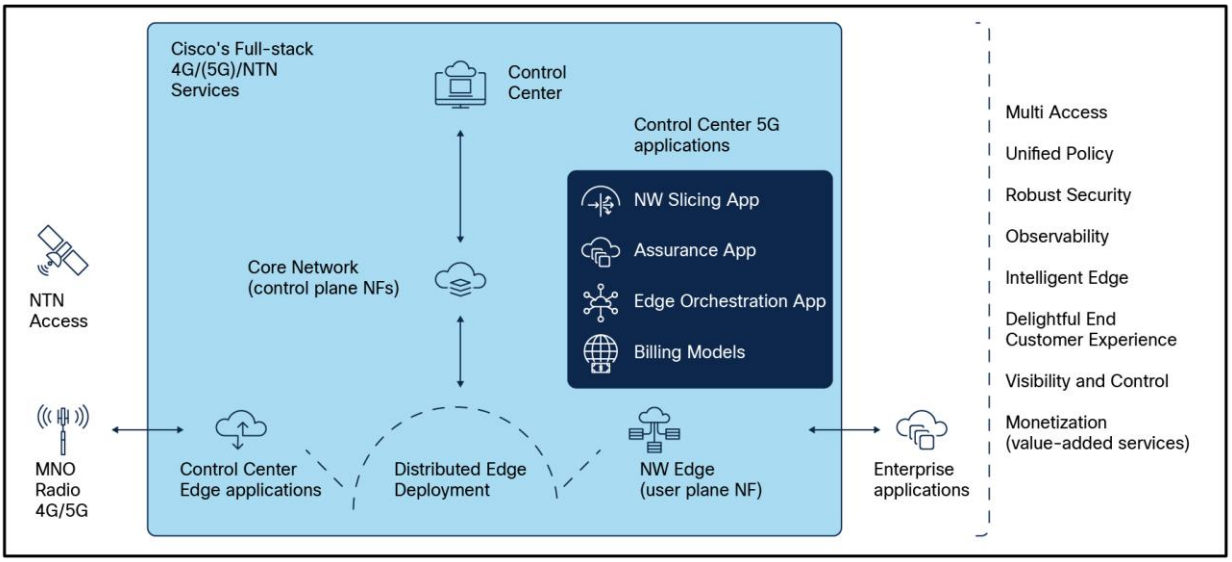

Figure 7.
Cisco Mobility Services Platform attributes

Benefits of collaborating with Cisco for an NTN direct-to-device solution

Unparalleled Network Experience

Cisco powers the majority of U.S. terrestrial network LTE traffic through its Packet Core solutions and has deployed the highest capacity 5G SA converged core networks with one of the nation's largest operators. This established infrastructure provides a robust foundation for integrating non-terrestrial networks.

Streamlined Integration for Satellite Network Operators

As satellite network operators expand to provide wholesale roaming connectivity for service providers who own end-customer relationships, Cisco facilitates this integration through standard S8 roaming protocols. With data centers strategically deployed across multiple countries and existing connectivity with regional mobile network operators, Cisco accelerates the connection of NTNs to service provider networks worldwide.

Precision-Based Service Assurance

Cisco Packet Core deployments are supported by Provider Connectivity Assurance sensors that enable microsecond-level latency monitoring and single packet drop detection. This comprehensive monitoring system tracks all relevant KPIs to ensure Packet Core services consistently operate within 3GPP release guidelines, with proactive remediation of any performance deviations.

Global Go-to-Market Capabilities

By integrating an NTN solution on the Cisco Mobility Services Platform with a satellite provider's infrastructure, partners gain access to Cisco's extensive channel network. These established relationships with enterprises and industries worldwide create powerful joint go-to-market opportunities that accelerate adoption and deployment.

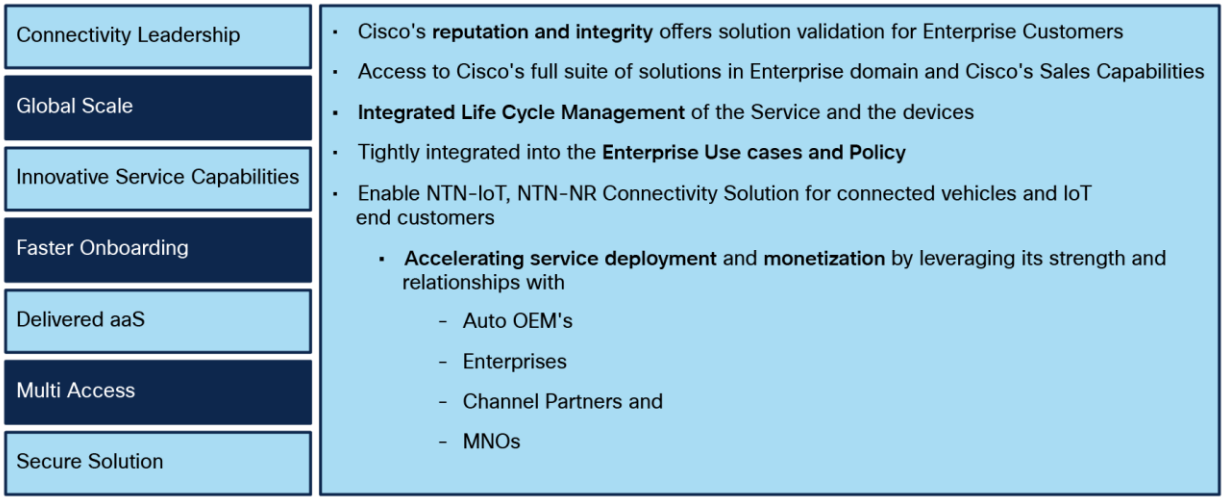

Figure 8.
Benefits of collaborating with Cisco for a NTN direct-to-device solution

Summary

Cisco provides satellite and mobile network providers with a secure, scalable, and programmable network foundation for NTN. Additionally, satellite providers can utilize Cisco's Non-Terrestrial Networking Solution and e-SIM orchestration technology to enhance their service offerings and access new markets with seamless connectivity across various networks. By integrating Cisco's robust infrastructure and as-a-Service solutions into your satellite ecosystem, you will future-proof your network, capture new market share, and position your brand as the leader in the global non-terrestrial connectivity revolution.

Learn more

- To learn more about Cisco's NTN solution, visit our solution website.
- To learn more about Cisco's Mobility Services Platform, visit the website: www.cisco.com/go/mobility-services-platform.
- To schedule a demonstration of Cisco's NTN solution, contact your Cisco sales representative.

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