Satellite Direct-to-Device: A Supplement for Terrestrial Cell Coverage

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Satellite Direct-to-Device Communications

Satellite Direct-to-Device is Different from Fixed Broadband Service

In recent years, technological innovation in satellite communications has created the potential for new connectivity services to be provided from space. As of March 2025, SpaceX's Starlink satellites are serving over five million customers worldwide, with nearly two million of these customers in the US. Starlink provides broadband to homes and businesses via a roof-mounted dish a foot or more in diameter that is somewhat similar to the dishes used for satellite TV over the last thirty years. Instead of simply receiving TV signals, Starlink's terminals support two-way broadband data transmission for streaming video and Internet access. However, with a typical monthly cost for residential service of $120 in the US, the Starlink broadband service is much more expensive than terrestrial broadband alternatives, like fiber, cable and fixed wireless access. Unsurprisingly, Starlink is mostly used by households in rural areas where limited or no terrestrial broadband services are available.

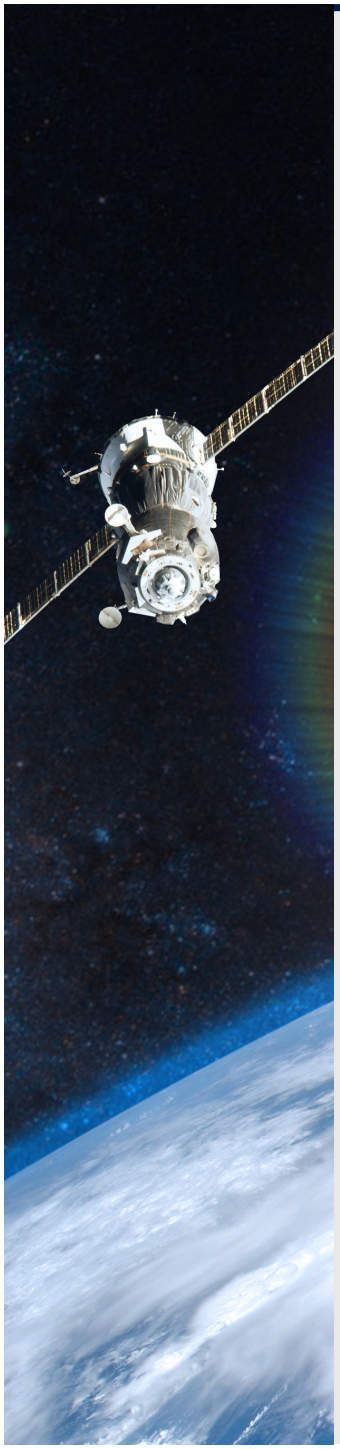
A new type of satellite service is now attracting attention, which is referred to as Direct-to-Device (D2D) or Direct-to-Cell (DTC) connectivity, and allows communications direct from a phone to a satellite, without relying on the large dish that is needed for Starlink's broadband service. Dedicated satellite phones such as those sold by Iridium have been marketed since the late 1990s, but are relatively large, expensive and do not offer the features expected on today's modern smartphones. However, in late 2022 Apple introduced emergency messaging capabilities via satellite on the iPhone 14, in partnership with the Globalstar satellite constellation. These services were initially limited to only sending texts to the emergency services for iPhone users who were outside terrestrial network coverage, but the feature has saved numerous lives, including in the Lahaina, HI fires in August 2023. A second D2D/DTC service is currently being launched by T-Mobile, in partnership with Starlink, using a small block of T-Mobile's terrestrial PCS spectrum to provide service. T-Mobile activated this service during the California wildfires in January 2025, serving almost 200,000 users with SMS and wireless alerts across Los Angeles.

Both Apple and T-Mobile are now expanding their service capabilities, with Apple introducing support for two-way non-emergency texts and iMessages as part of the iOS18 operating system update in fall 2024, and T-Mobile beginning beta testing of a basic texting service with Starlink in February 2025, with plans for commercial service introduction in July and additional services later in the year. Another similar D2D service using terrestrial cellular spectrum is planned by AST SpaceMobile, in partnership with AT&T and Verizon. The AST service is still at an early stage, with only 6 satellites launched to date, and larger, more capable satellites are under development to provide full commercial service. As a result, the current coverage is very intermittent and service is not available to the general public.

Satellite Direct-to-Device cannot match the performance of terrestrial networks, in terms of speed, capacity and building penetration.

Current Capabilities

Constraints on D2D Capabilities Include Speed, Capacity, and Building Penetration



At present, Apple's service only allows for basic texting and does not support voice or other data services. The service only works outdoors and outside the coverage of terrestrial networks, and requires the user to point the phone in the direction of the satellite to establish a link so that messages can be sent and received. In February 2025, Globalstar ordered more advanced satellites to provide additional capacity for Apple, but the iPhone-based services will still be limited to relatively low data rates and it is unclear whether voice will be supported.

The Starlink DTC service supports texting, including picture messaging on some phones, and is expected to expand to include data and app usage, and ultimately voice calling. Basic data services are expected to start becoming available later this year. It is important to realize that this service is completely different to Starlink's broadband service: it uses lower frequency spectrum to enable communications directly with a phone, rather than via a large dish. Starlink only uses a small 5MHz block within in the US, which means that the capacity of the system is very low. Although Starlink has demonstrated peak download speeds of up to 17Mbps during testing, Elon Musk acknowledged that "this is the current peak speed per beam and the beams are large, so this system is only effective where there is no existing cellular service." In other words, all of the hundreds or thousands of customers within a beam that is 12-20 miles across must share this bandwidth, and just like in a terrestrial cellular network, the spectrum must be re-used between adjacent beams, further limiting the available download speed for any individual user, in most cases to 1Mbps or less, with upload speeds even lower. For comparison, the average download speed experience for individual terrestrial mobile users in the US in fall 2024 ranged from 46Mbps to 158.5Mbps. In addition, just like Apple, T-Mobile tells potential customers that they need to be able to "see the sky" to be able to connect to the Starlink D2D service.

AST has demonstrated similar speeds to Starlink (of up to 21Mbps in a 5MHz block of spectrum), and this has allowed the company to complete short two-way video calls, although at present the video quality appears to be relatively low. AST has claimed that it will ultimately provide "broadband from space to your phone" but the same laws of physics that constrain Starlink's performance (large beams and restricted spectrum, resulting in a limited amount of capacity that must be shared by hundreds or even thousands of users) will also apply to AST. In fact AST's current beam size (48km or 30 miles diameter) is even larger than Starlink's beams, though AST now plans to acquire additional satellite spectrum to enhance capacity in future generations of satellites. As an interim measure, Verizon is providing satellite texting services on certain Android devices through a partnership with Skylo (and once again tells potential users that they "must be outside with line of sight to [the] satellite").

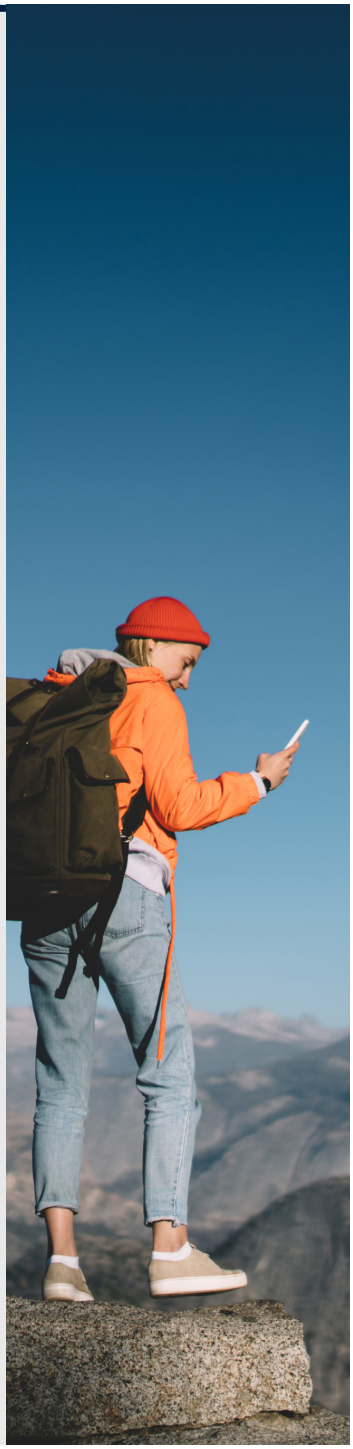
Constraints

Why do the laws of physics constrain the performance of D2D services?

When someone is using their phone on a terrestrial cellular network, they are communicating with a nearby tower, which is at most a few miles away. In comparison, the satellites used for D2D services are hundreds of miles away: Globalstar's satellites are 880 miles above the earth's surface, Starlink's satellites are just over 200 miles above the earth and AST plans to launch most of its satellites to an altitude of around 430 miles. The power of a signal falls off in proportion to the square of the distance traveled, which means that a satellite transmitting from one hundred times further away than a terrestrial cell tower will produce a signal 10,000 times weaker than the terrestrial tower. Some of this difference is compensated for by using more power on the satellite, along with a large antenna that focuses the beam on a particular location. However, for a given amount of spectrum, less data can be encoded in a weaker signal than in a stronger signal. In addition, the signal will not be able to penetrate reliably into a building, where (according to T-Mobile) "more than 80%" of network traffic "typically takes place." Instead users will at best be able to obtain intermittent coverage when they are standing near a window and a satellite happens to pass by on that side of the building.

Because the beams produced by the distant satellite spread out further, they are covering an area much larger than a typical terrestrial tower. A terrestrial tower in a suburban area may only cover a region that is 2-5 miles across, or 3-20 square miles, while a single satellite beam may cover a region that is 12-30 miles across, an area of 100-600 square miles, or 30 times greater. That means up to 30 times more people will have to share the same amount of capacity.

In addition, making significant amounts of spectrum available for satellite use is very difficult. Mobile operators now use hundreds of megahertz of spectrum in the US to provide service. Some of the higher capacity bands, such as the recently licensed C-band spectrum from 3.7-3.98GHz, are poorly suited to D2D service because the weaker power of satellite beams will not allow these frequencies to penetrate obstructions and support service inside buildings and cars or even under trees. Lower frequency spectrum is also very valuable: the 5MHz of spectrum that T-Mobile is making available for Starlink's D2D service was valued by the FCC at $4.8 billion back in 2004. And because of the large size of satellite beams, if a particular spectrum band is used on a satellite system to provide rural coverage, it may no longer be available for use on terrestrial towers to provide capacity in nearby cities. This has forced Apple and now AST SpaceMobile to look to existing satellite spectrum to provide sufficient capacity for their needs. However, only a small amount of spectrum is allocated for satellite use, and existing users such as airplanes and ships depend on this spectrum for safety-critical services. All of these constraints mean that D2D can never match the performance of terrestrial networks, in terms of speed, capacity and building penetration.



Satellite and Terrestrial

The Value for Satellite D2D is in Truly Remote Areas and Disaster Situations

There are a few parts of the country where it is not economically viable to deploy a terrestrial cell tower and the opportunity to cover these areas with D2D service is why mobile operators are partnering with satellite operators like Starlink and AST. AT&T said at its investor day in December 2024 that "you'll see us plug in [AST's] services on the edge where we don't cover, over the ocean, in the Grand Canyon, in places where, today, it doesn't pay for us to put up wireless cell towers to cover that footprint." Verizon has also stated that the aim of its partnership with AST is "to provide essential connectivity in remote corners of the U.S. where cellular signals are unreachable through traditional land-based infrastructure."

Why Do Mobile Operators Still Need to Construct Towers? The Limitations of D2D services Mean D2D is a Supplement, not a Substitute

When mobile operators and tower companies decide to build or upgrade a cell tower, they are making that investment because the cell tower would be economically viable: consumers want and need 5G coverage in that area. D2D is not an alternative, it is simply a last resort fall back solution outside of terrestrial coverage. That is valuable in truly remote areas, and it may also be useful in the event of a disaster, such as a hurricane or earthquake, that makes terrestrial infrastructure temporarily unavailable. However, the limitations of D2D service: much lower speeds, limited capacity and poor coverage in obstructed areas (like inside buildings), mean that D2D is not a true substitute for terrestrial cellular service.

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Summary

- Satellite D2D is different from satellite broadband service: it uses lower frequency spectrum to enable communications directly with a phone, rather than via a large dish.
- There are constraints on D2D in terms of speed, capacity and building penetration.
- Satellite D2D is valuable in truly remote areas and in the event of a disaster.
- Limitations of D2D services mean D2D is not a true substitute for terrestrial cellular service.