2018 ACE SCHOOL & RUS SYMPOSIUM
TERMINUS
CONNECTING POINTS OF OPPORTUNITY

The Future of Broadband Balloons
(and some other crazy options)

Ben Pidek, PE

Mid-State Consultants, Inc.

Balloons that Provide the Internet?

- Several internet balloon projects, but we will focus on the most well known, Project Loon

What is it?

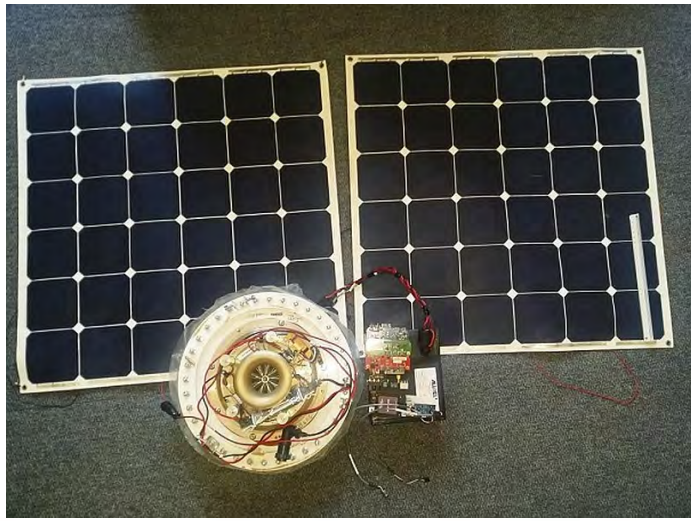
- Named Project Loon because even Google found the idea a little “loony”
- Made from sheets of polyethylene, 15m wide by 12m and 0.003 in thick
  - Roughly the size of a tennis court
  - Filled with helium

How the Balloons Work

- Float on wind currents in the stratosphere at 60,000-75,000 ft
  - Significantly higher than commercial air traffic (45,000 ft)
  - High above weather events
  - Steady winds (5-20 mph) and minimal turbulence
  - 2 balloons in 1 – outer balloon is filled with helium that lifts, while the inner balloon takes on air to descend or vents to rise (like a boat ballast)
- Designed to last 100 days
  - Thin atmosphere offers less protection from UV radiation (1% of the air pressure at sea level)
  - Balloons experience dramatic temperature swings (down to -90°C)
- All the equipment is highly energy-efficient
  - Powered entirely by solar panels during the day and batteries for use during the night (which are also charged by the solar panels).

How the Balloons Work (Cont.)

- Equipment housed in small container that hangs underneath the balloon.
  - Circuit boards for control system
  - Radio antennas for communicating with other balloons and internet antennas on the ground (through LTE)
  - Lithium ion batteries to store solar power



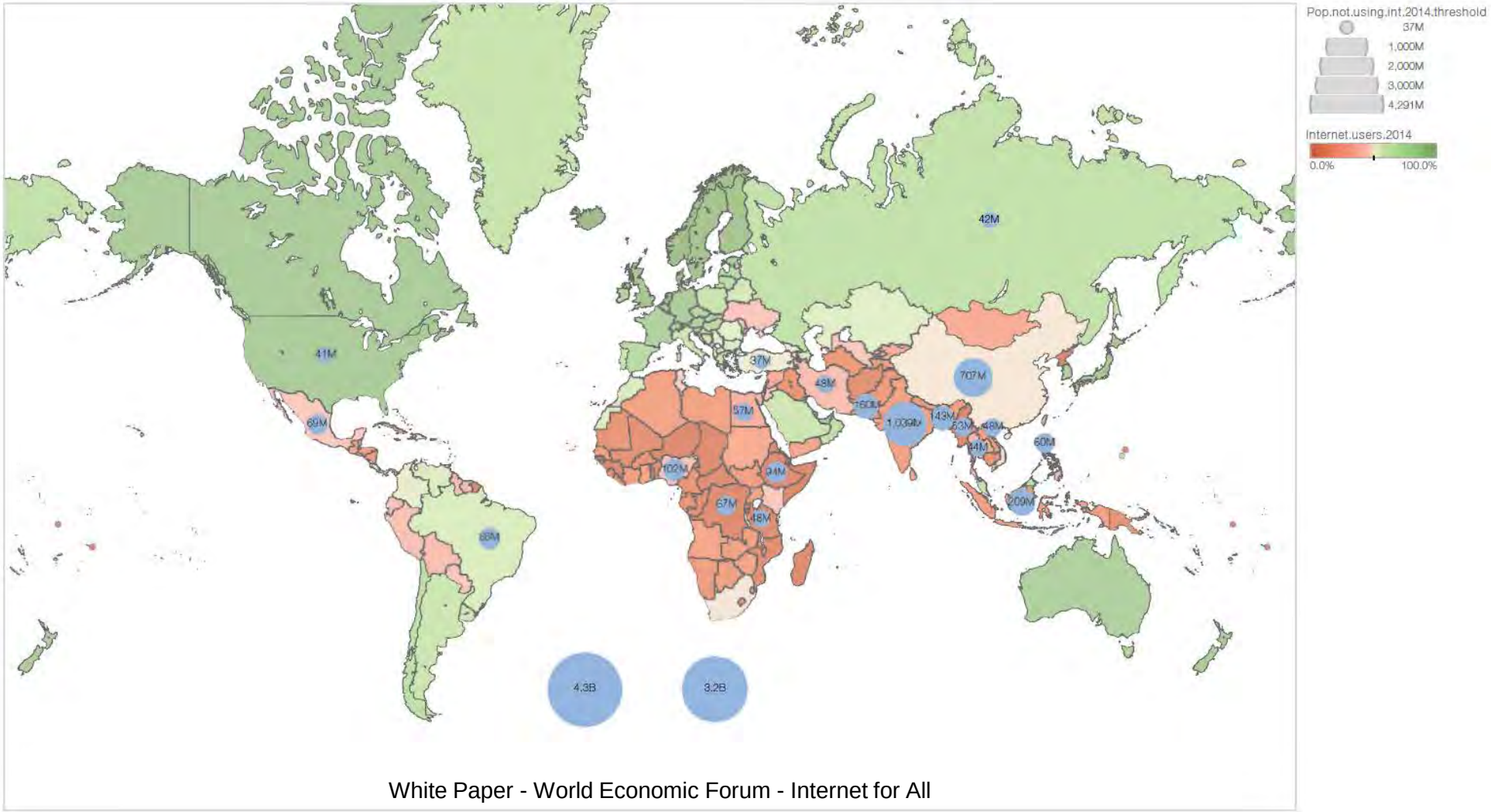
Evolution of Loon Payload

How does the connection work?

- Balloons are not an ISP. End-users connect via Loon to existing network operators in their country that partner with Loon.
- Taken the most essential components of a cell tower and redesigned them to be light enough and durable enough to be carried by a balloon.
  - Originally used unlicensed frequencies (2.5 GHz and 5.8 GHz) but now uses LTE base station (eNodeB)
  - Coordinates frequency use with local providers/operators
  - High-speed directional link for air-to-ground communications
  - Balloons use Ubiquiti Networks Rocket M2 radio for balloon-to-balloon and balloon-to-ground communications
  - Ground stations use Ubiquiti Rocket M5 radios.
- 80 km coverage area
- Not intended to stay in one spot but to be used in a circular sequence. As one goes out of range of antennas on ground, another takes its place to provide continuous internet connection

Why?

- More than 55% of the world's population is still not online

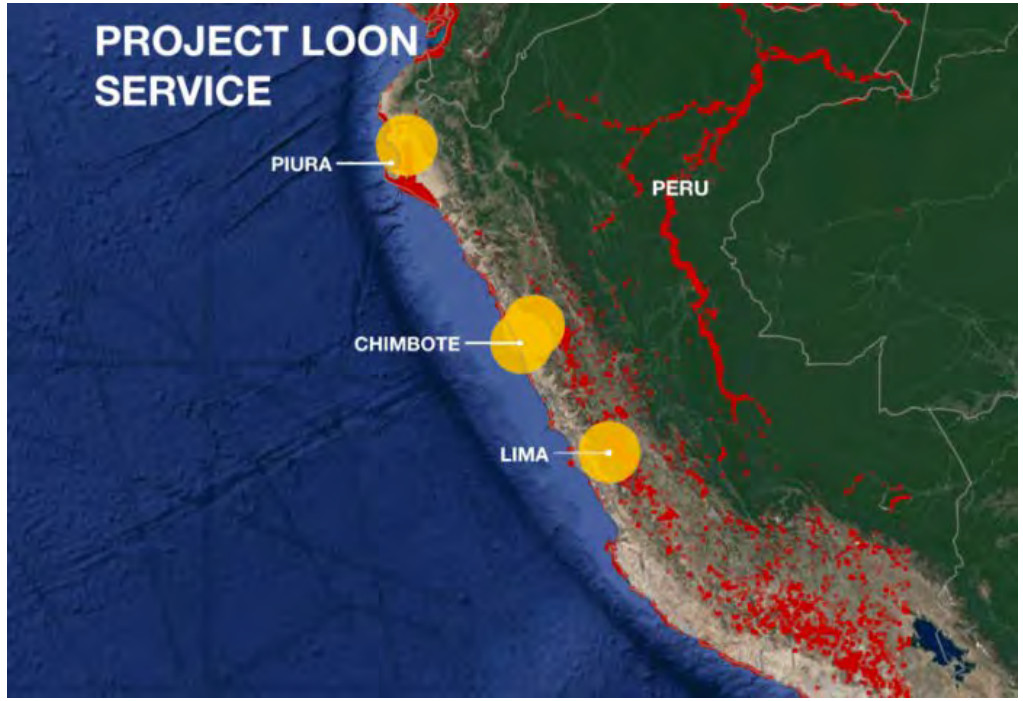


White Paper - World Economic Forum - Internet for All

Trials – Peru (March-April 2017)

- Infrastructure including telecommunications networks seriously damaged by flooding from extreme rains
- Telefonica and Loon had already been testing in Peru for several months prior to the floods so infrastructure was already in place.
  - Provided internet access to customers across 40,000 square kilometers totaling 160 GBs of data
  - O3b networks, Level 3 and Ecologistica Peru set up ground stations for connecting balloons to the Internet backbone

Flood areas in red



Side note – O3b is short for Other 3 billion users

Trials – Puerto Rico and Virgin Islands (Oct.-Dec. 2017)

- Infrastructure devastated by Hurricane Maria (95.2% of cell sites across island were knocked out)
  - Worked with FCC, FAA, FEMA, spectrum partners and international aviation authorities to help deliver basic connectivity to 200,000 people for several months.
  - FCC approved use of 30 balloons
  - Change in normal mode of operation
    - balloons kept in clusters over tight area
    - Used satellite capacity from O3b to provide connectivity (0.5 Gbps – 1.0 Gbps link)
    - Partnered with at&t for LTE
  - Considered as an experiment, so actual data rates have not yet been disclosed.
    - Connectivity was reduced at night due to low power operation

Coverage - How many would it take?

Each balloon can cover 5000 square kilometers.
The Earth is 510.1 million square kilometers.

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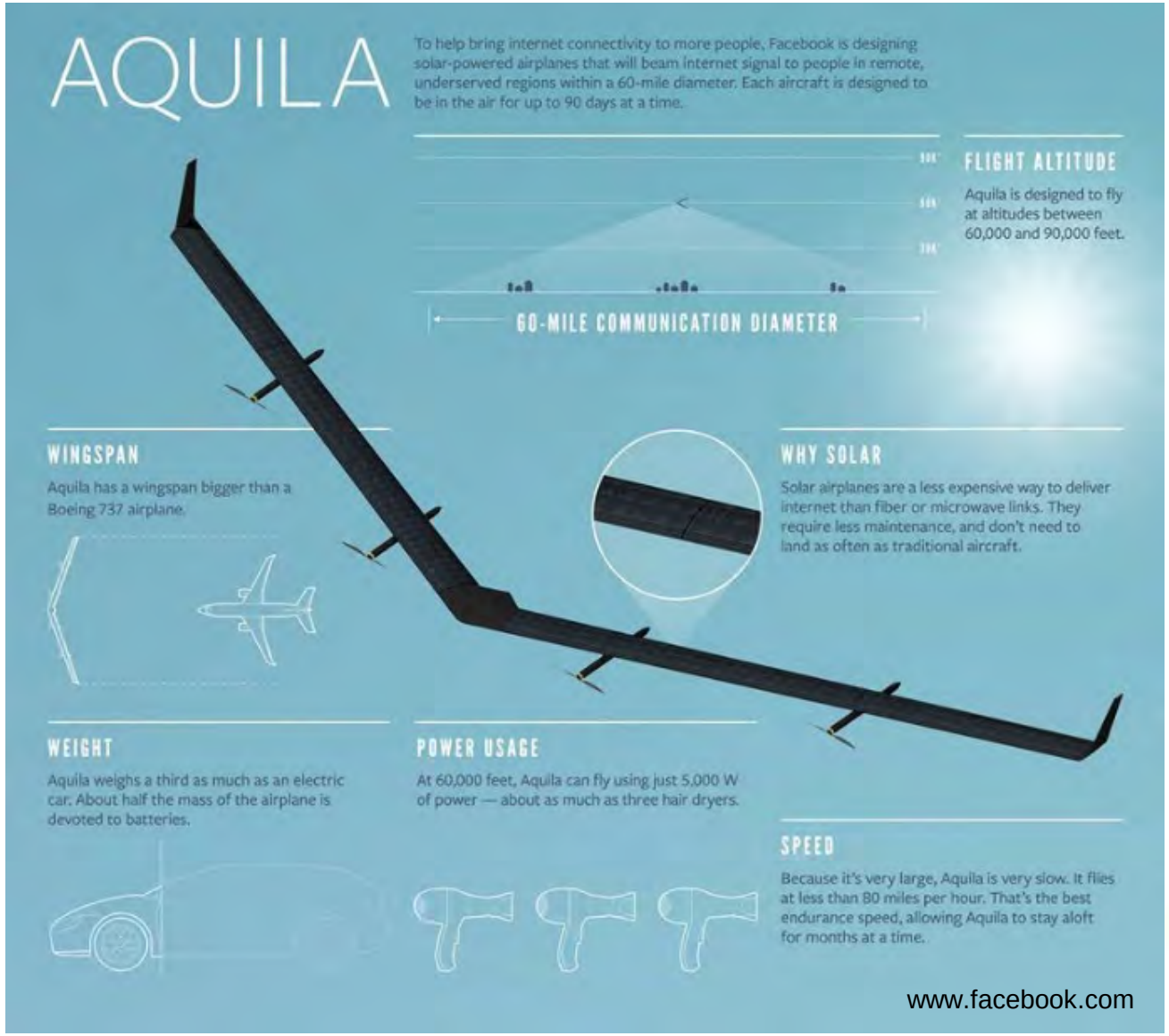
Other Options for Rural Internet

Drones

Satellites

Facebook Aquila

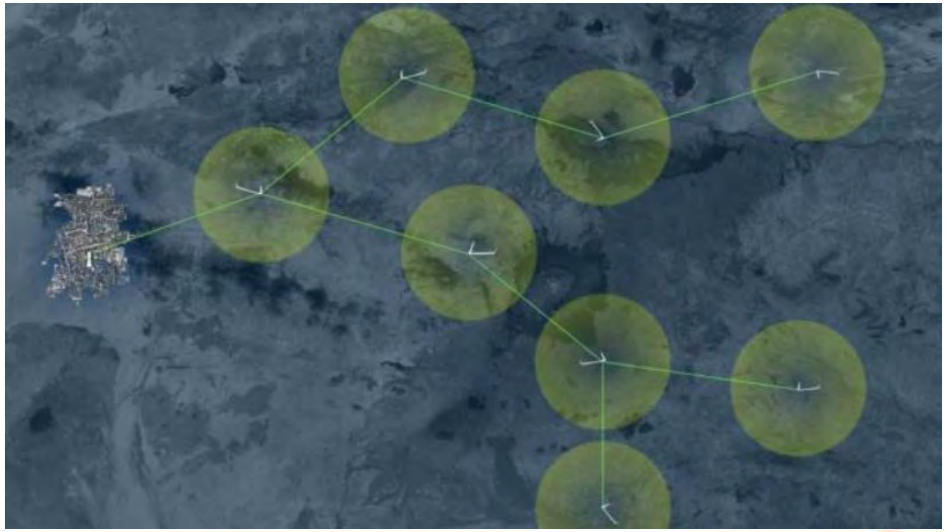


World of the Drones – Coming Soon to a Rural Area Near You?

- Aquila
  - For use as an atmospheric satellite intended to be a relay station for providing internet access
  - Prototype has a wingspan roughly the same size as a Boeing 737
  - Flying wing configuration with the upper surface covered in solar cells to power it's 4 electric motors
  - Batteries which compose half the aircraft's weight are used for night flight
  - Intended to fly at 90,000 ft during the day and 60,000 ft at night (better watch out for balloons!!!)
  - Service duration intended to be 3 months
  - Designed to fly slowly (around 80 mph)
  - Uses the same power as 3 hair dryers (5,000 W) when flying at 60,000 ft
  - Test flight of prototype in June 2016, crashed during landing (encountered unexpected wind gusts)
  - Initial design was modified/enhanced for stability and second test flight occurred in May 2017

How Does the Connection Work?

- Unlike the high-altitude balloons, the drone will use lasers for communication
  - Creates a laser net in the sky by aiming lasers where needed that are precise enough to hit a dime more than 10 miles away while in motion (no radio spectrum)
  - Data can be transmitted at 10 Gbps
  - Ground station will transmit a radio internet signal to a mother aircraft, which will then feed other aircraft in the constellation using free space laser communications
  - 80 km coverage area



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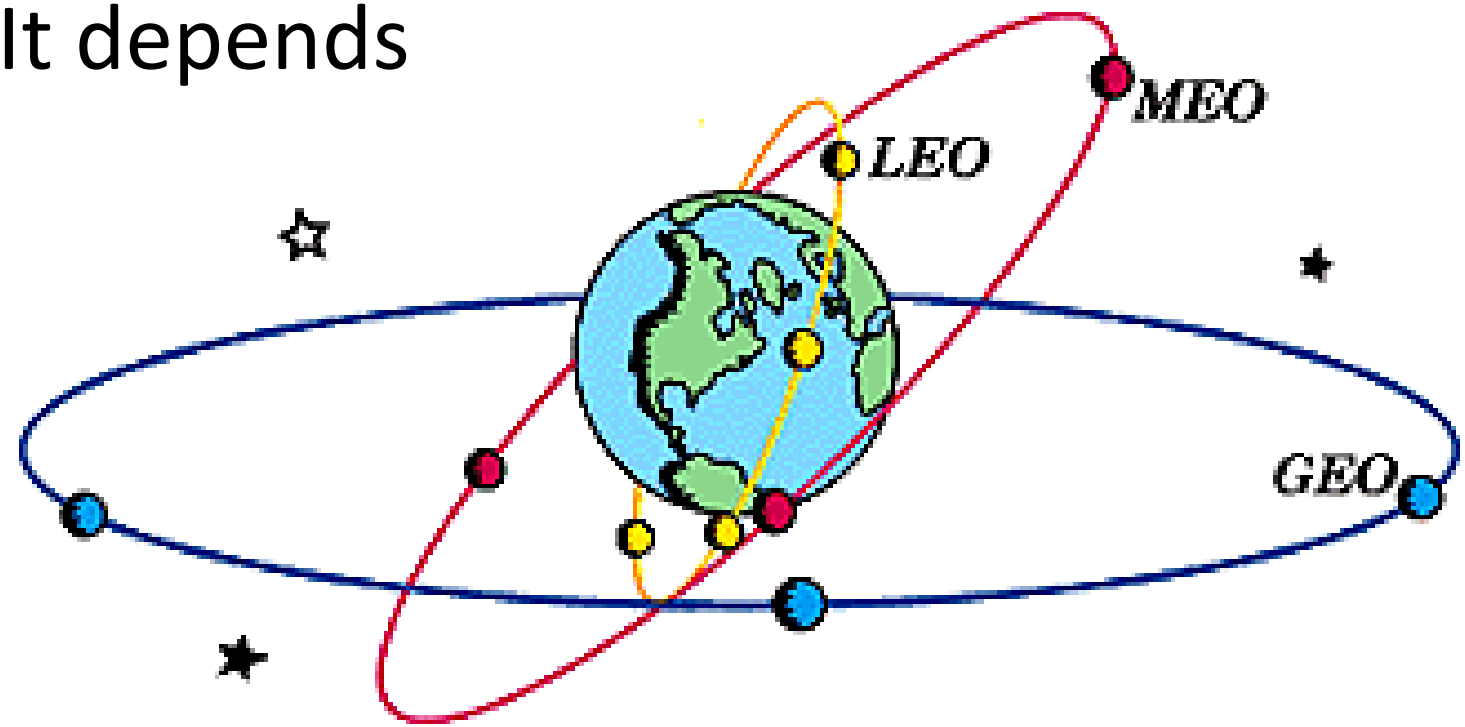
We are Not Alone Out There

Internet Provided by Satellite

- Primarily provided today by Geostationary satellites
- Several companies want to take a new approach with Low Earth Orbit satellites:
  - SpaceX and OneWeb just 2 examples
- Most satellites occupy one of three different orbits:
  - Lower-Earth Orbit (LEO) – 100-1,240 miles
  - Medium-Earth Orbit (MEO) – 1,240-22,236 miles (most common at 12,600 miles)
  - Geostationary Orbit (GEO) – 22,236 miles above sea level

How many satellites would you need?

It depends



LEO – 40 to 80

MEO – 8 to 20 For basic coverage but not capacity

GEO – 3

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Trade-offs Between GEO and LEO

- Latency
  - LEO satellites have lower latency for time-critical services due to the closer proximity to Earth
  - GEO satellites benefit from well-engineered satellite services with echo cancellation and IP acceleration and have provided backhaul to cellular networks for many years
- Coverage
  - GEO satellites appear stationary from the ground while LEO satellites move constantly with the service being handed off between satellites
- Efficiency
  - LEO satellites are moving all the time and spend a significant portion of their orbit over oceans and unpopulated areas while GEO satellites are focused permanently over a region
- Complexity
  - LEO constellations are more complex to operate with more costly ground antennas due to the need for tracking and seamless handoff between satellites.

Trade-offs Between GEO and LEO (Cont.)

- Cost
  - LEO are small satellites that are much less costly to manufacture and have less hardware overall, but many more are needed in the constellation for operation which usually offsets the cost differential with GEO satellites
  - Receiver equipment for LEO satellites is less bulky and costly due to higher C/N signal ratio due to closer proximity
  - GEO satellites have a longer transmission distance and received signal level is weak. More expensive low noise amplifiers are needed in receivers and better signal processing algorithms both of which increase the cost of ground station equipment
- Frequency Spectrum
  - Frequency coordination is more challenging for LEO satellites because the constellation is always moving and there is significant coverage overlap between them
- Time to Market
  - GEO satellites can be deployed progressively and begin operating immediately, while many LEO satellites must be deployed before regular service can be provided to a region

Just How Many LEO Satellites?

OneWeb plans to launch **700**

SpaceX plans to launch **4425**

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OneWeb LEO

- Formerly known as WorldVu Ltd.
- Satellites will orbit at an altitude of approximately 750 miles and will use Ku band frequencies
- Acquired the spectrum formerly owned by SkyBridge
- Satellites weigh less than 500 lbs each (originally planned to be 250 lbs)
- Plan to start launching satellites in May 2018
- Investors include Virgin, Qualcomm, SoftBank Group and Airbus
- In February 2017, announced that it had sold most of the capacity of its initial satellites and was considering quadrupling the size of its constellation by adding 1,972 additional satellites

SpaceX LEO

- Known as “StarLink”
- Satellites will orbit at an altitude of approximately 690-825 miles
- Use Ka and Ku band frequencies
- Satellites weigh less than 850 lbs each
- Plan to start launching satellites in 2019
- In May 2017 SpaceX announced in update to Senate Commerce Committee that it planned to launch an additional 7500 satellites for operation even closer to the ground that will boost capacity and reduce latency in heavily populated areas.
- Projected capability to handle 50% of all backhaul communications traffic and up to 10% of all local internet traffic in high-density cites

Hasn’t this been tried before?

Anyone recognize a 1990s Iridium satellite?

Reality Check

- LEO satellites might be cheaper than GEO satellites, but are they 1000 times cheaper?
- Controlling costs is important – remember, this is for internet service in developing countries/regions
  - Subscription cost and satellite dishes must be cheap
- Mistakes can be very costly!!!

SpaceX exploding rocket blew up more than Facebook's internet dreams

BY ELIZABETH SEGRAN 1 MINUTE READ

Last week's SpaceX explosion dealt a big blow to Facebook, destroying a $200 million satellite that promised to extend the social media network's reach across Africa.

- What about End-of-Life? More space junk

Economics of the Options

- What could these new technologies cost:
  - Stratospheric Balloons
    - R&D – Undisclosed
    - Each Balloon – “tens of thousand of dollars”
  - Facebook Drone
    - R&D - $20 Million so far
    - Each Drone – “needs to be much cheaper if the world is going to deploy a fleet of them
  - LEO:
    - OneWeb - $3 Billion estimate
    - SpaceX - $10 Billion estimate (by Elon Musk in 2015)

Economics of the Options (Cont.)

- $60 Million - SpaceX Falcon 9 can carry approximately 11,000 lbs, but doesn't need refurbishing, just inspections prior to launch
- $5.7 Million - Rocket Lab can carry 330 lbs and completed its second test launch from New Zeeland in Jan. 2018
- $1.5 Million – Vector (startup) rocket is anticipated to have a payload capacity of 132 lbs for smaller, cheaper "CubeSats" which are the size of a shoebox

Bandwidth

- LTE Stratospheric Balloons: 100-108 Mbps
  - 10 Mbps to the user
- Laser Drones: 10 Gbps
  - User data rate unknown at this time
- Satellites:
  - OneWeb LEO – 8 Gbps per satellite
    - 50 Mbps to the user
  - SpaceX LEO - 17-23 Gbps per satellite
    - 1 Gbps to the user anticipated to be possible (intend to offer different tiered packages)

Summary

- No matter how “loony” it may seem, balloons and satellites for providing internet are all real things
  - Maybe drones too in the near future
- Significant cost in R&D and deployment of all options
- How does this factor into helping rural communities gain affordable internet access? What is affordable?