

Backhaul Communications at 10's of Gbps

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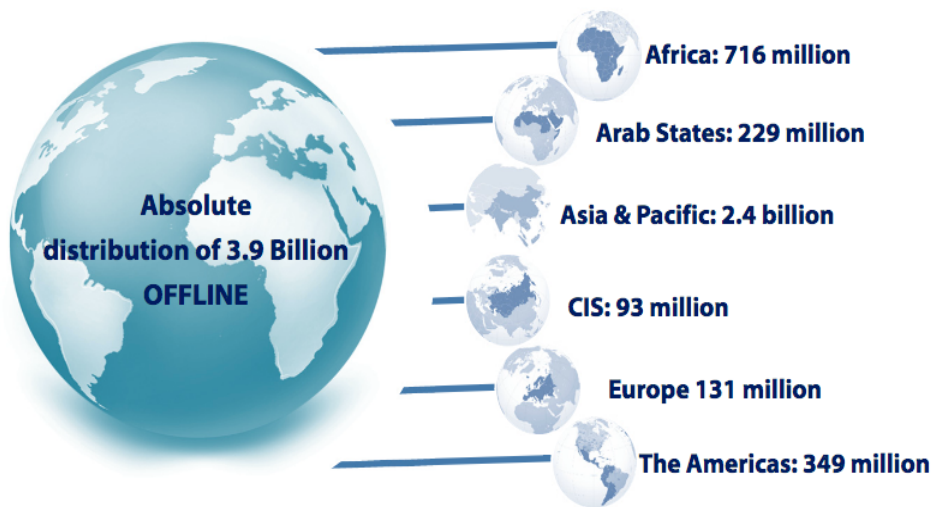
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Large Number of People are Still Unconnected

WORLD INTERNET USAGE AND POPULATION STATISTICS JUNE 30, 2016 - Update						
World Regions	Population (2016 Est.)	Population % of World	Internet Users 30 June 2016	Penetration Rate (% Pop.)	Growth 2000-2016	Table % Users
<u>Asia</u>	4,052,652,889	55.2 %	1,846,212,654	45.6 %	1,515.2%	50.2 %
<u>Europe</u>	832,073,224	11.3 %	614,979,903	73.9 %	485.2%	16.7 %
<u>Latin America / Caribbean</u>	626,119,788	8.5 %	384,751,302	61.5 %	2,029.4%	10.5 %
<u>Africa</u>	1,185,529,578	16.2 %	340,783,342	28.7 %	7,448.8%	9.3 %
<u>North America</u>	359,492,293	4.9 %	320,067,193	89.0 %	196.1%	8.7 %
<u>Middle East</u>	246,700,900	3.4 %	141,489,765	57.4 %	4,207.4%	3.8 %
<u>Oceania / Australia</u>	37,590,820	0.5 %	27,540,654	73.3 %	261.4%	0.8 %
<u>WORLD TOTAL</u>	7,340,159,492	100.0 %	3,675,824,813	50.1 %	918.3%	100.0 %

Reference: <http://www.internetworldstats.com/stats.htm>

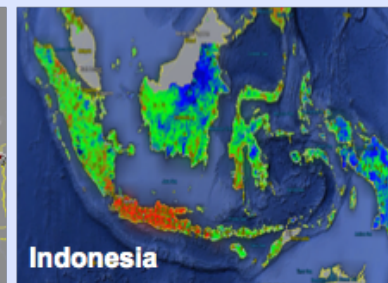
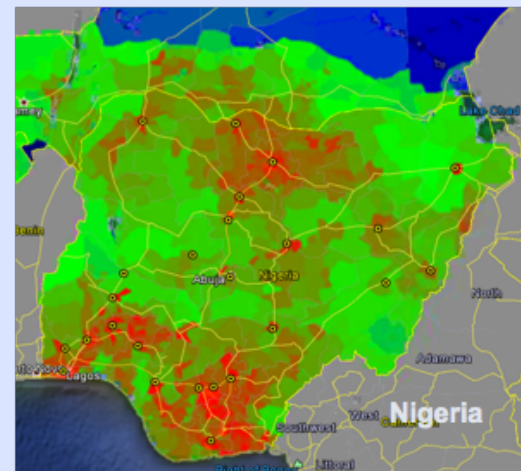
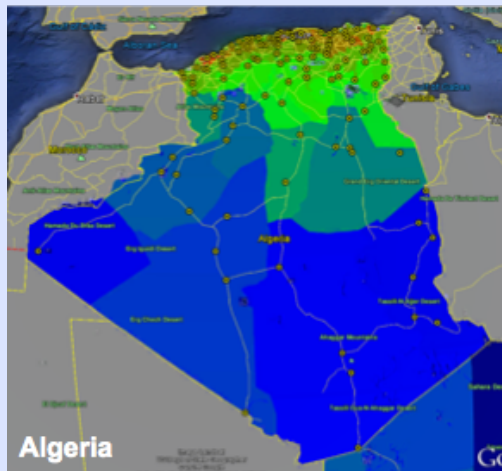
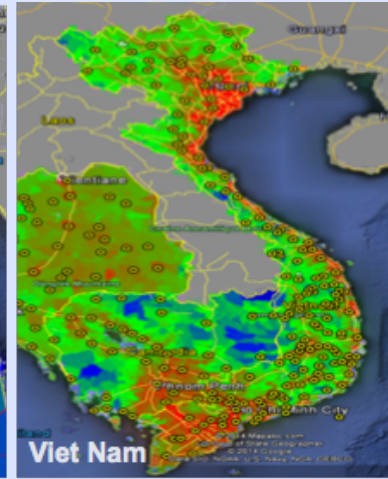
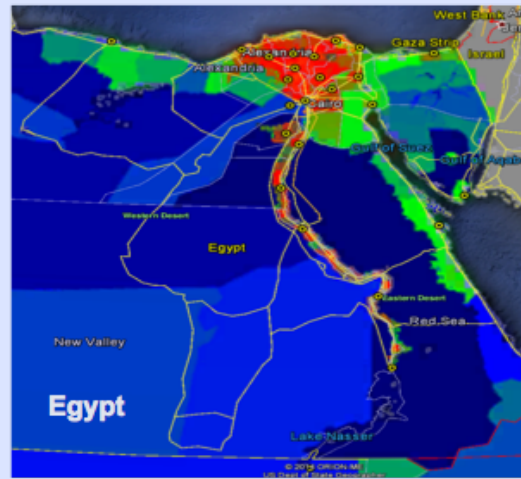
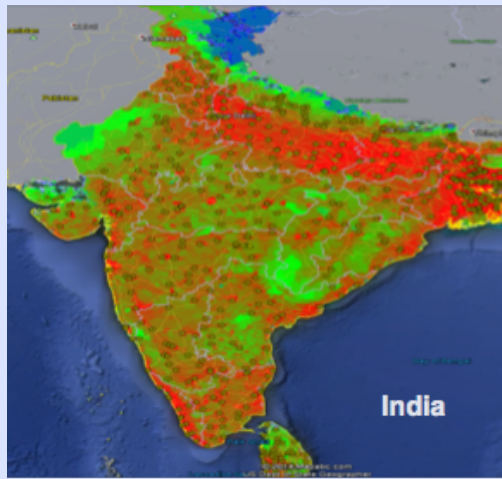
- Globally, about 4 billion people are yet to be connected
- Within the connected public, some are under-connected with no access to 4G/LTE



Africa	75%
Arab States	58%
Asia-Pacific	58%
CIS	33%
Europe	21%
The Americas	35%
Developed	22%
Least Developed	85%

Reference: http://broadbandcommission.org/Documents/ITU_discussion-paper_Davos2017.pdf

1000x Population Distribution Among Unconnected Countries



Circles designate fiber PoPs
Population density:
Red: High
Green: Medium
Blue: Low

One Connectivity Solution Does Not Fit All

- 3 orders of magnitude population distribution among the countries
- Different countries require very different solution-sets
- Deployment costs vary greatly with:
 - User density
 - Distance from internet point-of-presence
 - Infrastructure availability
- Need to allocate capacity where needed
- User access aggregation decreases deployment cost

Increasing Demand for Data

- ~10X increases in data capacity demand every 5 years
- Continuous increase at this pace is expected
 - 1,000 times increase in capacity by 2030 (in 15 years)!
- Current communication techniques must scale and develop to satisfy demand

≥ 100 Tbps - The throughput required to connect the unconnected by 2020

- 3 billion people
- Peak capacity per user:
 - 10 GB/month (no video)
 - 30 GB/month (with video)
 - ≈ 80 to 250 kb/s network capacity peruser
 - Takes into account those that are on Internet simultaneously

Approaches

1

Terrestrial Infrastructure

Above and below ground fiber
Tower-to-tower links

2

High Altitude Platforms (HAPs)

Solar-powered planes
Balloons/Dirigibles/Blimps

3

Satellites

LEO, MEO, GEO

Communications Technologies

1

Laser (optical) Communications

- **Very high data-rates**
- **No spectrum regulation**
- **Challenge of laser beam pointing**
- **Challenge of atmospheric attenuation**

2

Millimeter-Wave Communications

- **Medium and high data-rates**
- **Some spectrum regulations**
- **Moderate beam pointing challenge**
- **Attenuation by heavy rain**

3

RF Communications

- **Medium data-rates**
- **Severe spectrum allocation issues**
- **No real beam pointing or atmospheric attenuation issues**

Challenges

- **Terrestrial** infrastructure in developing countries is limited
- **HAPs** (High Altitude Platforms) still at low TRL (Technology Readiness Level)
- **Satellites**: To make the Internet network over developing countries cost effective, extremely high capacity per satellite needed
 - GEO satellite capacity is increasing greatly, but hampered by the capability of the gateway links.
 - Current Ka-band gateway uplink & downlink data-rate is low (<2Gbps)
 - The next milestone is Tbps aggregated satellite downlink capacity

Current Satellites: Expensive & Capacity-Limited

GEO Satellites (~40,000km)

- Advantage: Coverage area and fixed ground stations
- Challenge: Latency, launch costs, scalability, limited slots
 - 1 Tbps aggregated downlink data-rate RF/Microwave telecom satellite technology at hand
 - Need ≈ 100 GEO satellites to achieve 100Tbps

MEO Satellites (~12,000km)

- Key challenge: Higher cosmic radiation levels
- 16X link improvement over GEO.
- Lower latency than GEO

LEO Satellites (~1,000km)

- Key challenge: Number of satellites required in constellation
 - Assume 1 Gbps aggregated data-rate/satellite
 - Total capacity = 1 Tbps assuming 1000 satellites
 - Satisfies only $1/100^{\text{th}}$ of the demand