Deeper Peering (US)

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Why interconnect deeper?

- Additional reliance on the internet since last century
  - Latency sensitive services are now on the IP network
  - (E.G.) VOIP, VPN, CDN, Video, Gaming
- Even more reliance on the internet in the future
  - (E.G.) VR, AR, SD-WAN, SASE, more CDN & Video, Edge
- Reduce reliance on “Tier1” interconnection markets
- Better cost economics for access circuits
  - Access component is larger than IP cost

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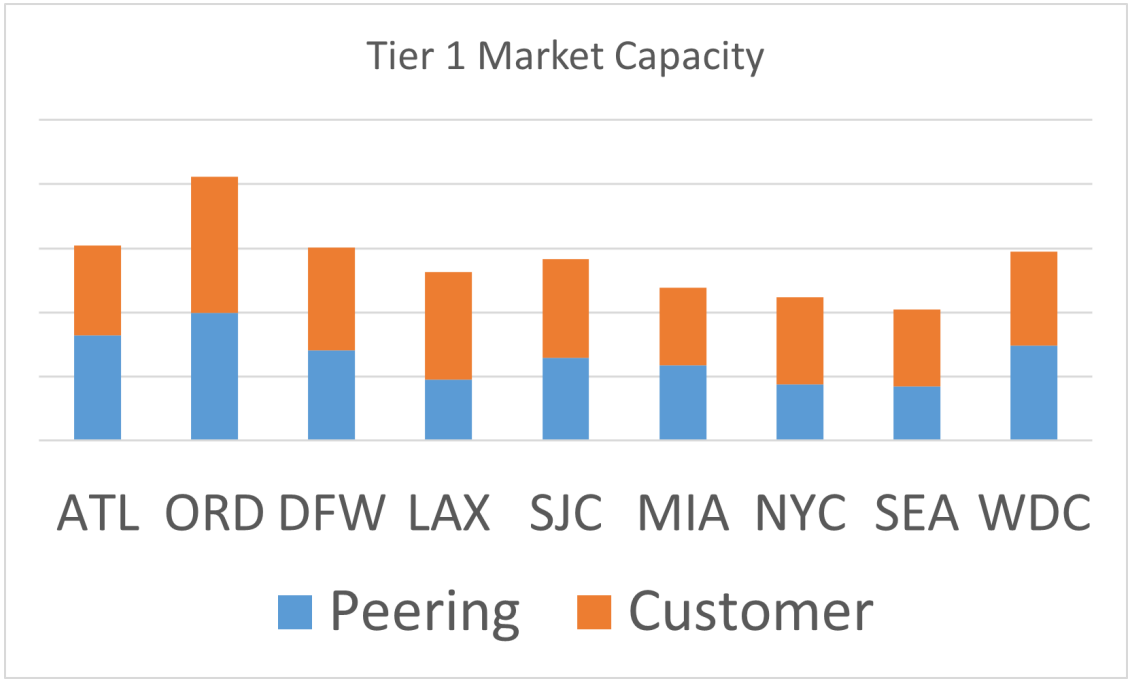
Hurdles for Deeper Peering

- Outdated Architecture
  - Some carriers still haven’t merged peers and customers to same edge PEs. Route reflection. ($$$)
- Capacity Planning
  - Smaller markets may need to provide failover capacity to larger markets ($$$)
- Customer procurement mentality (chicken & egg)
  - Without local peering, customers long line into larger markets since their traffic routes there anyway to get off-net
  - Without local customers, no traffic/justification for peering in smaller markets

IP Port Capacity Bottleneck



- Chicago, Dallas and Atlanta comprise 40% of total IP port capacity out of the existing nine Tier1 interconnectivity markets
- Decreasing reliance on the US for international connectivity

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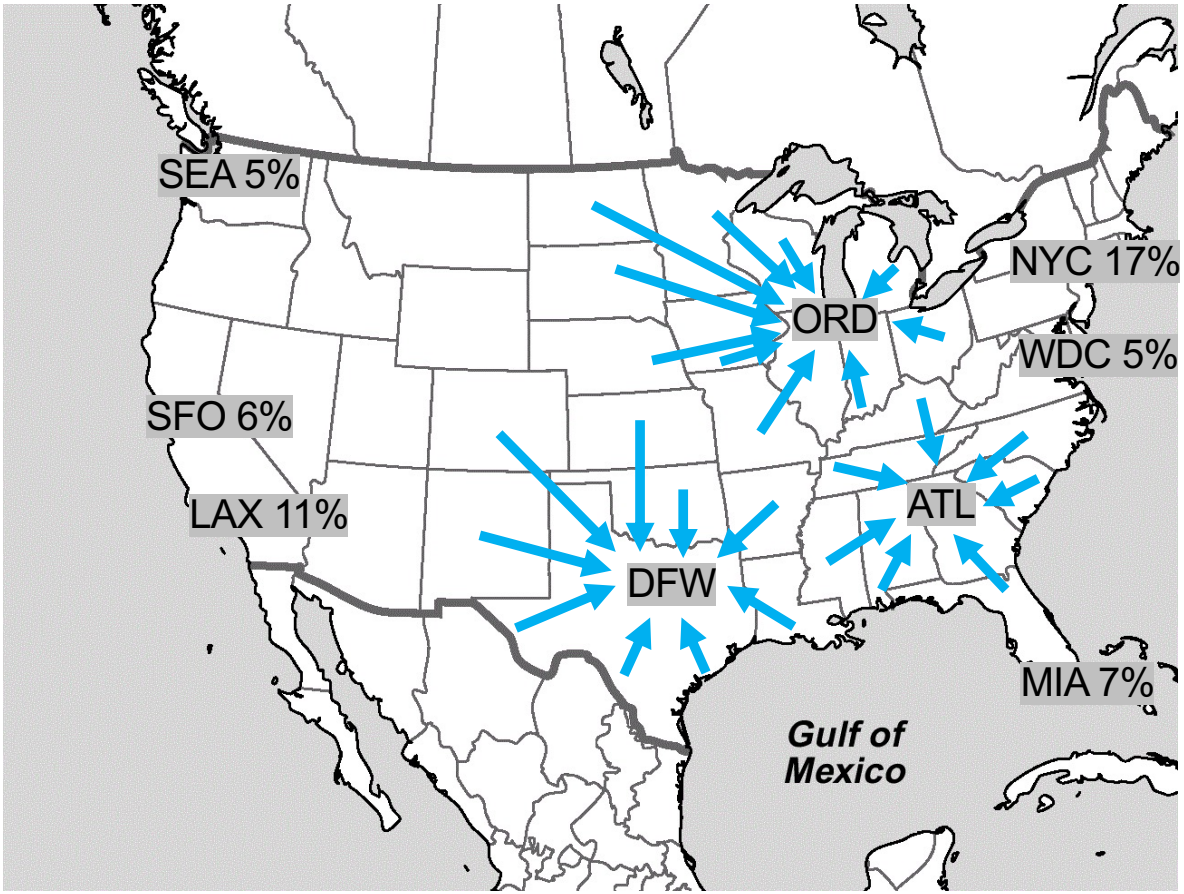
Chicago, Dallas and Atlanta (24/50 States and 47% of the US Population)

- Chicago (20% Pop)
  - IL, OH, MI, IN, MO, WI, MN, IA, NE, SD, ND
- Dallas (16% Pop)
  - TX, CO, LA, AR, OK, KS, NM
- Atlanta (14% Pop)
  - GA, NC, SC, KY, TN, AL, MS, N FL



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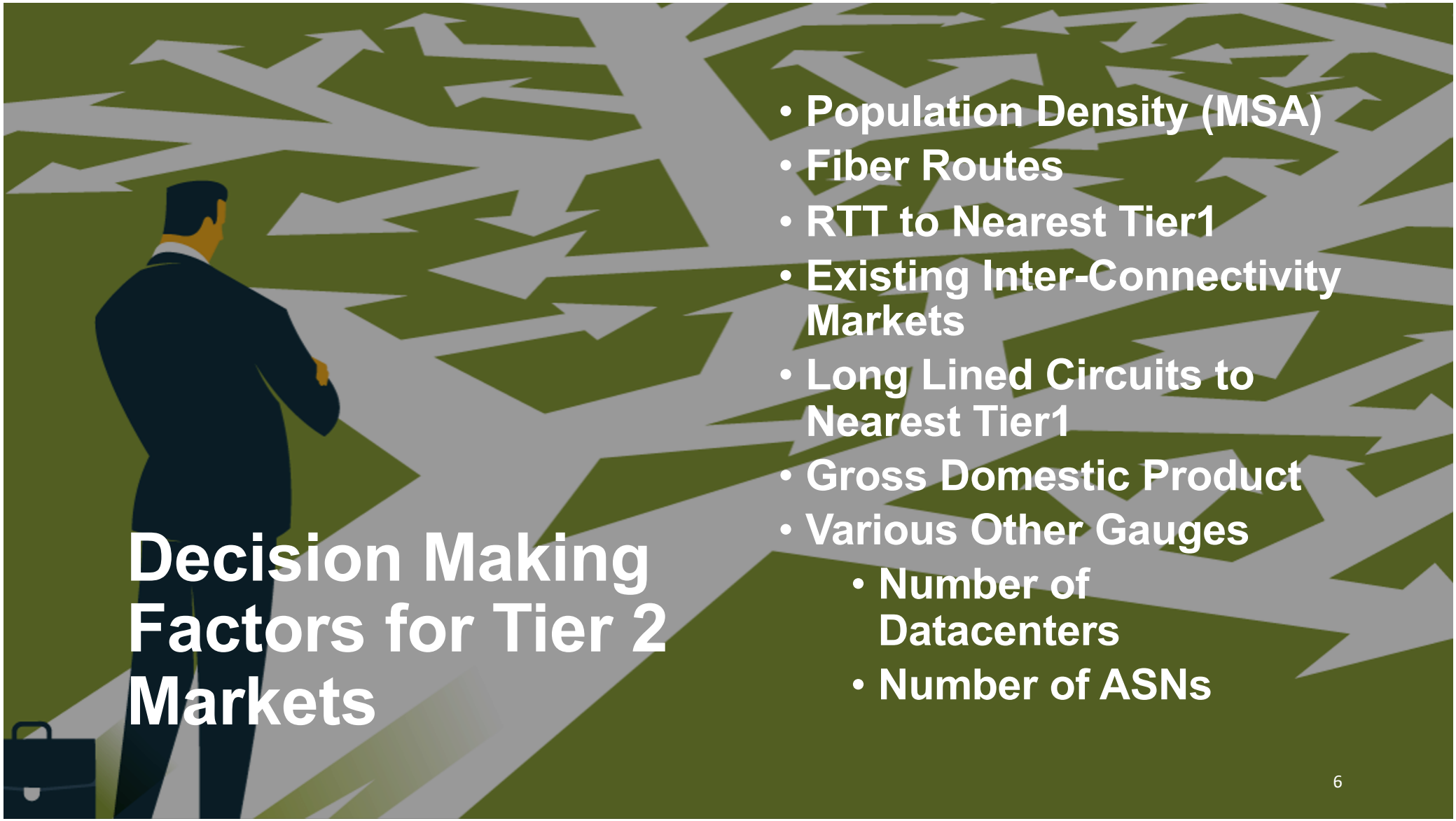

Decision Making Factors for Tier 2 Markets

- Population Density (MSA)
- Fiber Routes
- RTT to Nearest Tier1
- Existing Inter-Connectivity Markets
- Long Lined Circuits to Nearest Tier1
- Gross Domestic Product
- Various Other Gauges
  - Number of Datacenters
  - Number of ASNs

US Tier 2 Selection

Tier 1	MSA	GDP	DCs
New York	1	1	32
Los Angeles	2	2	36
Chicago	3	3	21
Dallas	4	6	23
Wash DC	6	5	35
Miami	7	12	22
Atlanta	9	10	25
San Fran	12	4	25
Seattle	15	11	16

[1]Cleveland would be #6 MSA and #10 in GDP with Columbus and Cincinnati

RTT reduction with these nine cities is nearly 8ms

Tier 2	MSA	GDP	DCs	Peers	RTT
Houston	5	7	14	6	5
Philly	8	9	10	5	3
Phoenix	10	16	20	10	10
Boston	11	8	30	8	5
Minn/StP	16	15	25	9	9
Denver	19	18	22	19	14
St Louis	20	22	19	5	6
Cleveland[1]	34	31	8	2	9
Nashville[2]	36	34	9	3	7

[2]Nashville would be #18 MSA and #20 in GDP with Memphis

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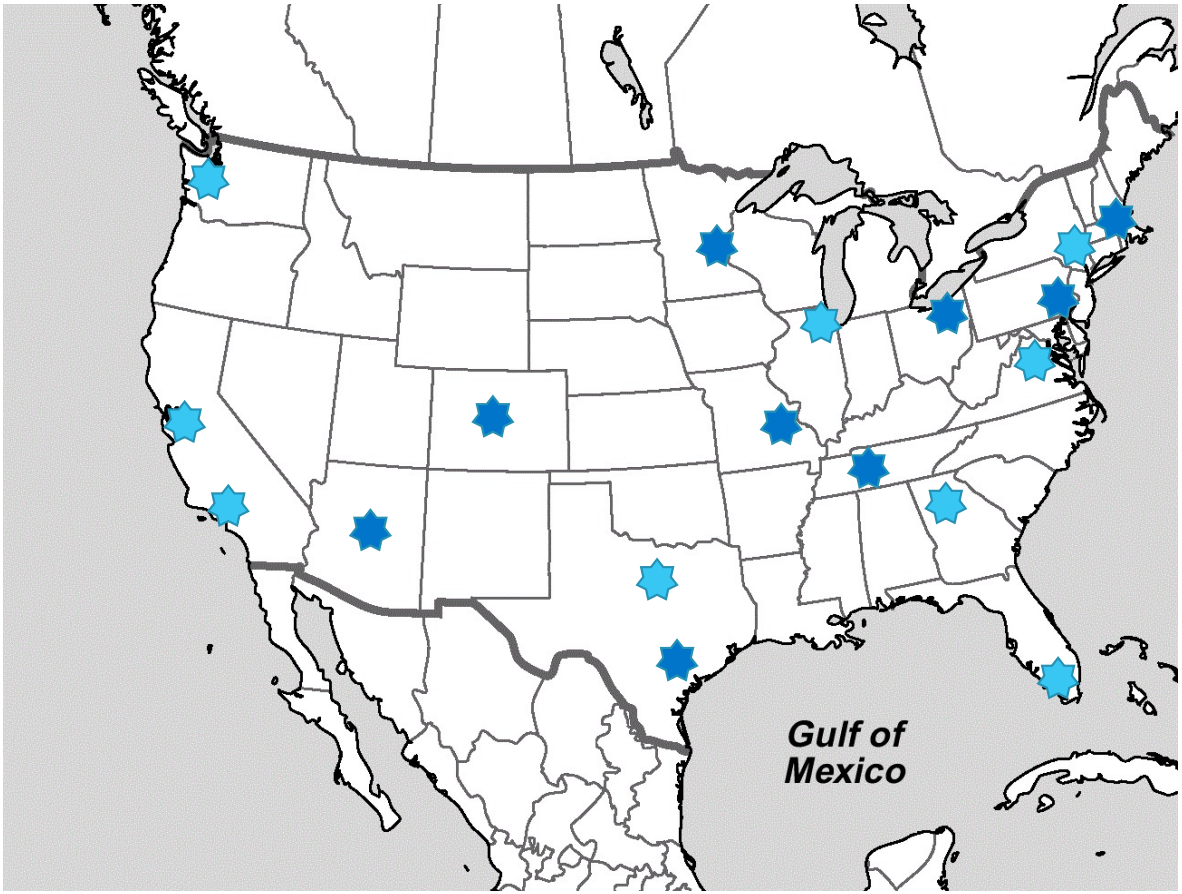
Peering Markets in US

Tier 1 Markets

Seattle, San Francisco, Los Angeles, Dallas, Chicago, Atlanta, New York, Northern Virginia and Miami

New Tier 2 Markets

Phoenix, Denver, Houston, Minneapolis, St Louis, Nashville, Cleveland, Philadelphia, and Boston



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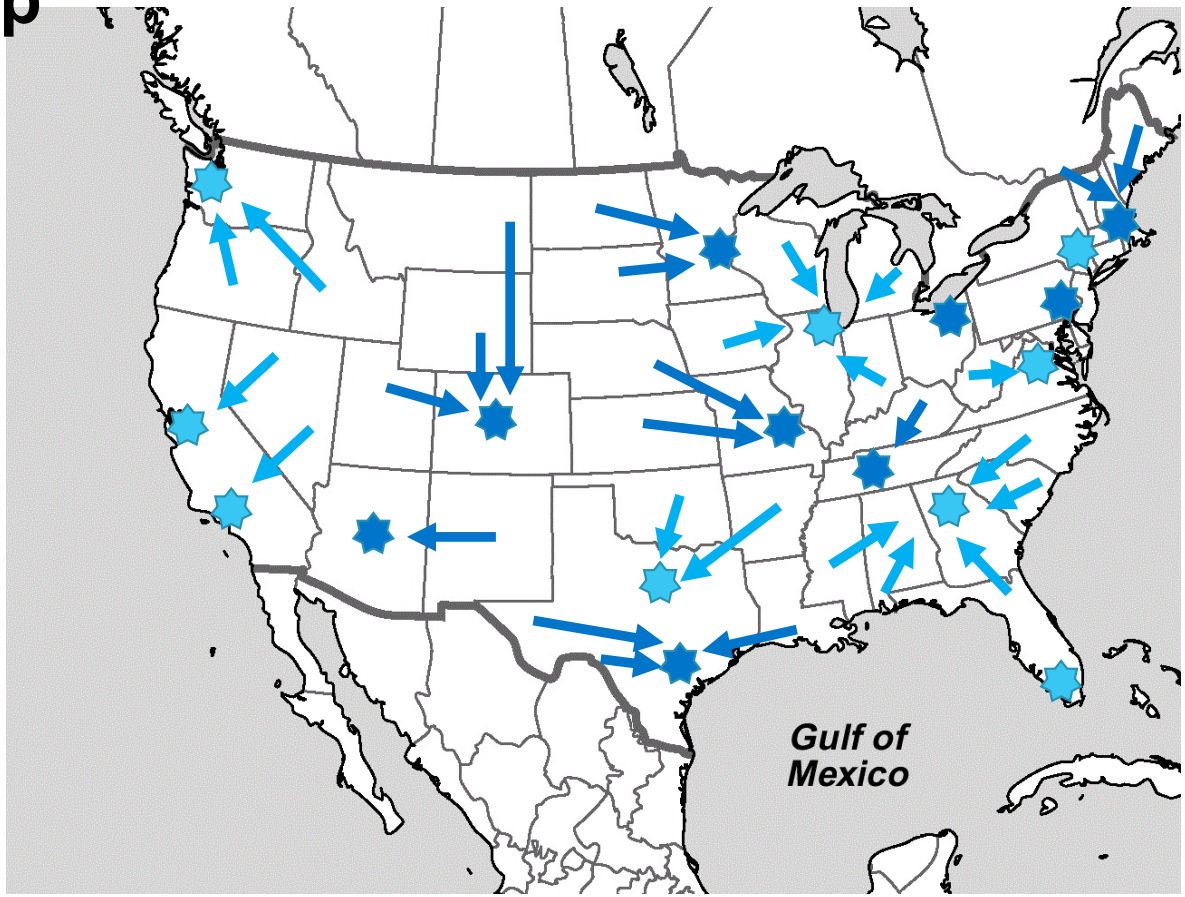
Distribution of State Pop to Tier1/2 Markets

Chicago (11% Pop)
- IL, MI, IN, WI, IA

Dallas (6% Pop)
- TX, AR, OK, KS

Atlanta (10% Pop)
- GA, NC, SC, AL, MS, N FL

Reduction of RTT of states adjacent to Tier2 markets



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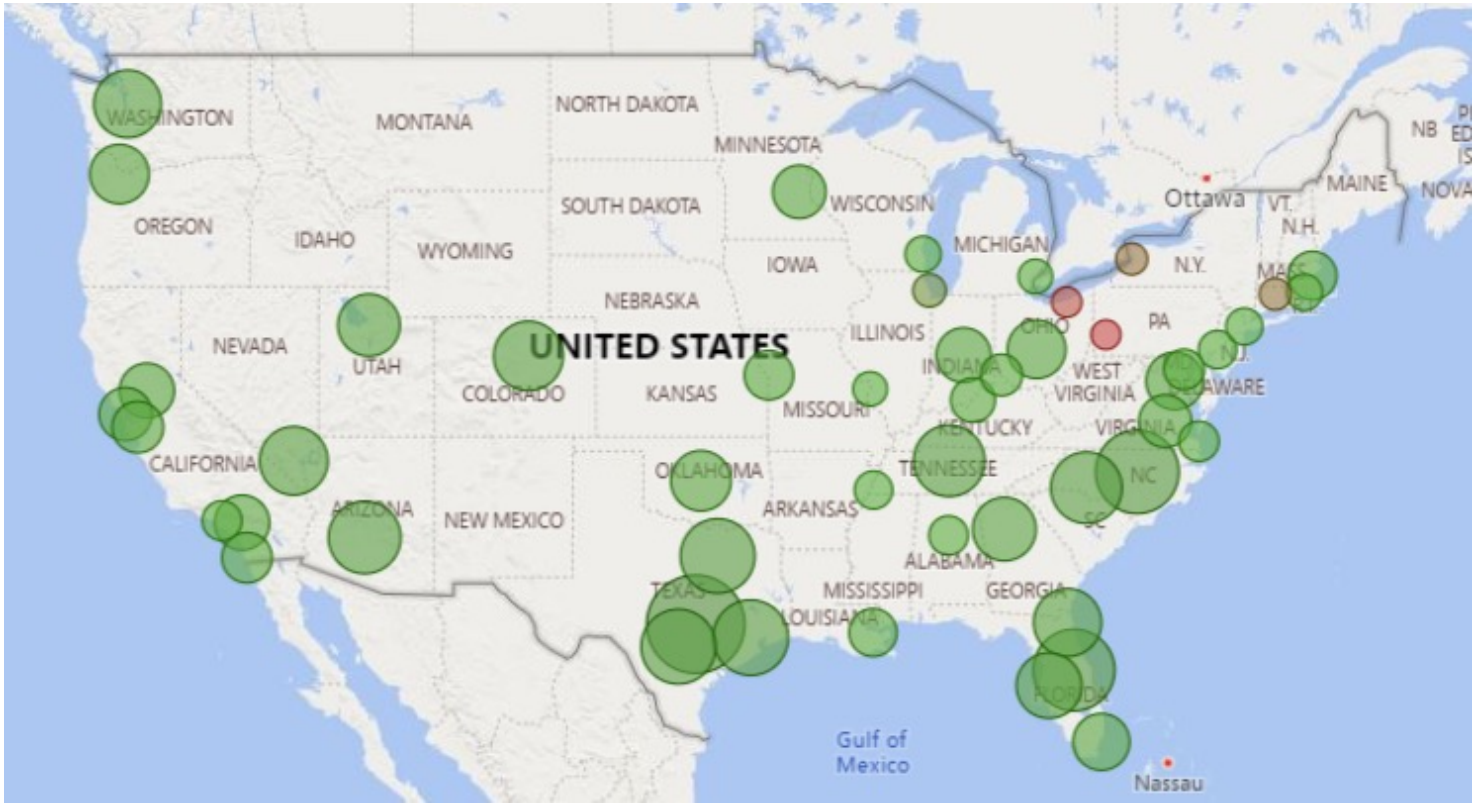
MSA Population % Change Last 10 Years

- SE US is fastest growing region over last 10 years
- Adapt network to population and migration patterns



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Looking ahead, Tier3?

13 – Riverside
24 – San Antonio
26 – Sacramento
28 – Pittsburgh
29 – Austin
30 – Cincinnati
31 – Kansas City
32 – Columbus
33 – Indianapolis
35 – San Jose
37 – Virginia Beach

RTT reduction with these nine cities is nearly 6ms

Tier 3	MSA	GDP	DCs	Peers	RTT
Detroit	14	14	13	1	7
San Diego	17	17	8	0	5
Tampa	18	24	11	1	5
Baltimore	21	19	7	0	3
Charlotte[1]	22	21	15	0	5
Orlando	23	30	4	2	6
Portland	25	23	16	6	4
Las Vegas	27	36	8	2	5
Boise	77	81	5	1	11

[1]Charlotte would be #15 MSA and #17 in GDP with Raleigh/Cary

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Peering Markets in EU

Tier 1 Markets

Madrid, London, Paris, Amsterdam, Frankfurt, Milan and Stockholm

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Peering Markets in EU

Tier 1 Markets

Madrid, London, Paris, Amsterdam, Frankfurt, Milan and Stockholm

New Tier 2 Markets

Marseilles, Vienna, Dusseldorf, Sofia, Copenhagen, Budapest and Warsaw

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Summary

- There is too much reliance on interconnection in Tier 1 interconnectivity markets in the US
  - Fat Pipe / Skinny Backbone
- Large swaths of the country has traffic travelling > 1000 miles to switch off-net
  - Both because customers are buying in remote markets or buying in local markets but traffic is carried to remote market since there is no peering in local market
- Internet and applications riding on IP are a more integral part of business (and life) than twenty years ago

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Recommendations

- Carriers need to offer customers internet access with rich connectivity options in local markets, not just in existing Tier 1 peering markets

- Lumen has updated peering requirements to mandate peering in all Tier 1 interconnectivity markets and 2/3 of Tier 2 interconnectivity markets in the US