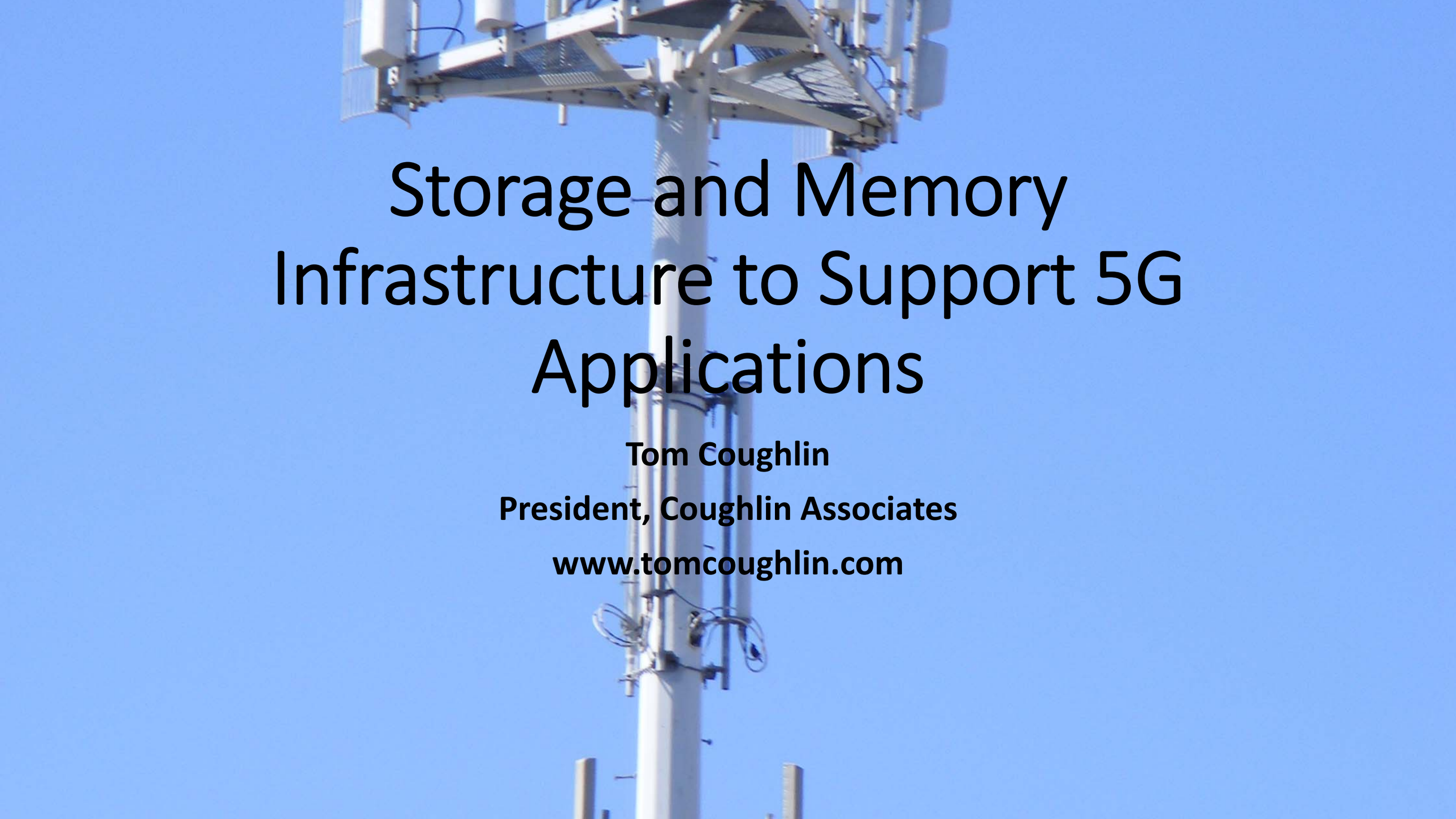


Storage and Memory Infrastructure to Support 5G Applications

Tom Coughlin

President, Coughlin Associates

www.tomcoughlin.com

Outline

- 5G and its Implementation
- Storage and Memory Technologies
- Emerging Non-Volatile Memory Technologies
- New Network Storage for the Edge and Data Center
- Conclusions

5G Technology

- Stands for 5th generation mobile technology and will allow cell phone technology with very high bandwidth
- Whereas 4G provides data rates of 5—100 Mbps, 5G will provide up to 10 Gbps
- In addition to increasing the data transfer speeds of mobile networks 5G technology is supposed to be more scalable, allow greater connectivity and provide greater energy efficiency
- 5G is aimed at enabling applications from IoT to vehicular telematics to faster video downloads and streaming services

From Huawei Slide on 5G Vision, 2015

5G Implementation

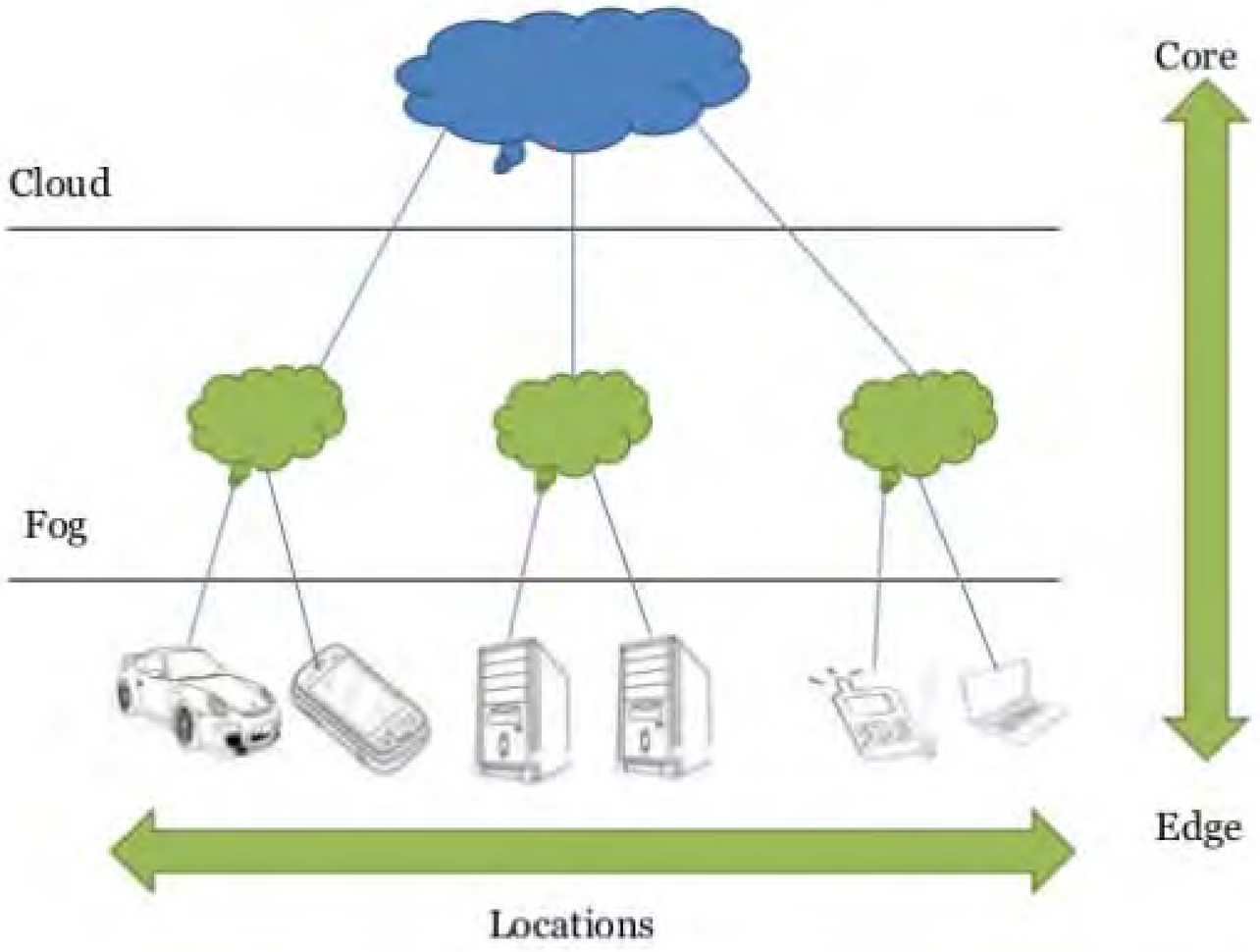
- In early 2018 Qualcomm demonstration 5G technology in San Francisco, CA and Frankfurt, Germany. In Frankfurt browsing jumped from 56 Mbps for a median 4G user connection to >490 Mbps for a median 5G user connection. In San Francisco these speeds increased from 71 Mbps to 1.4 Gbps.
- Significant investments in cell tower infrastructure will be required and telecom companies must agree upon standards for 5G networks.
- Will some cell towers be “data centers?”

The cloud and the fog

- The Cloud refers to compute resources, including storage, located in large data centers
- The Fog refers to local networks that connect thing (e.g. IoT) together
- Local fog networks may connect to the Internet

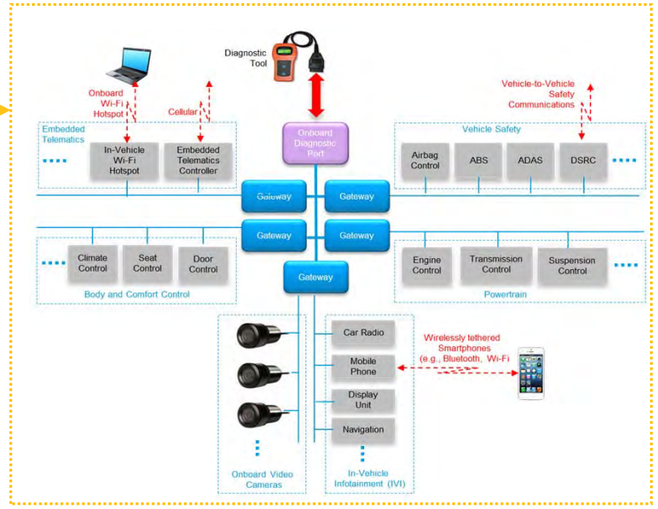
The Role of the Fog

Source: IOT at the Network Edge, http://www.nojitter.com/post/240172079/iot-at-the-network-edge



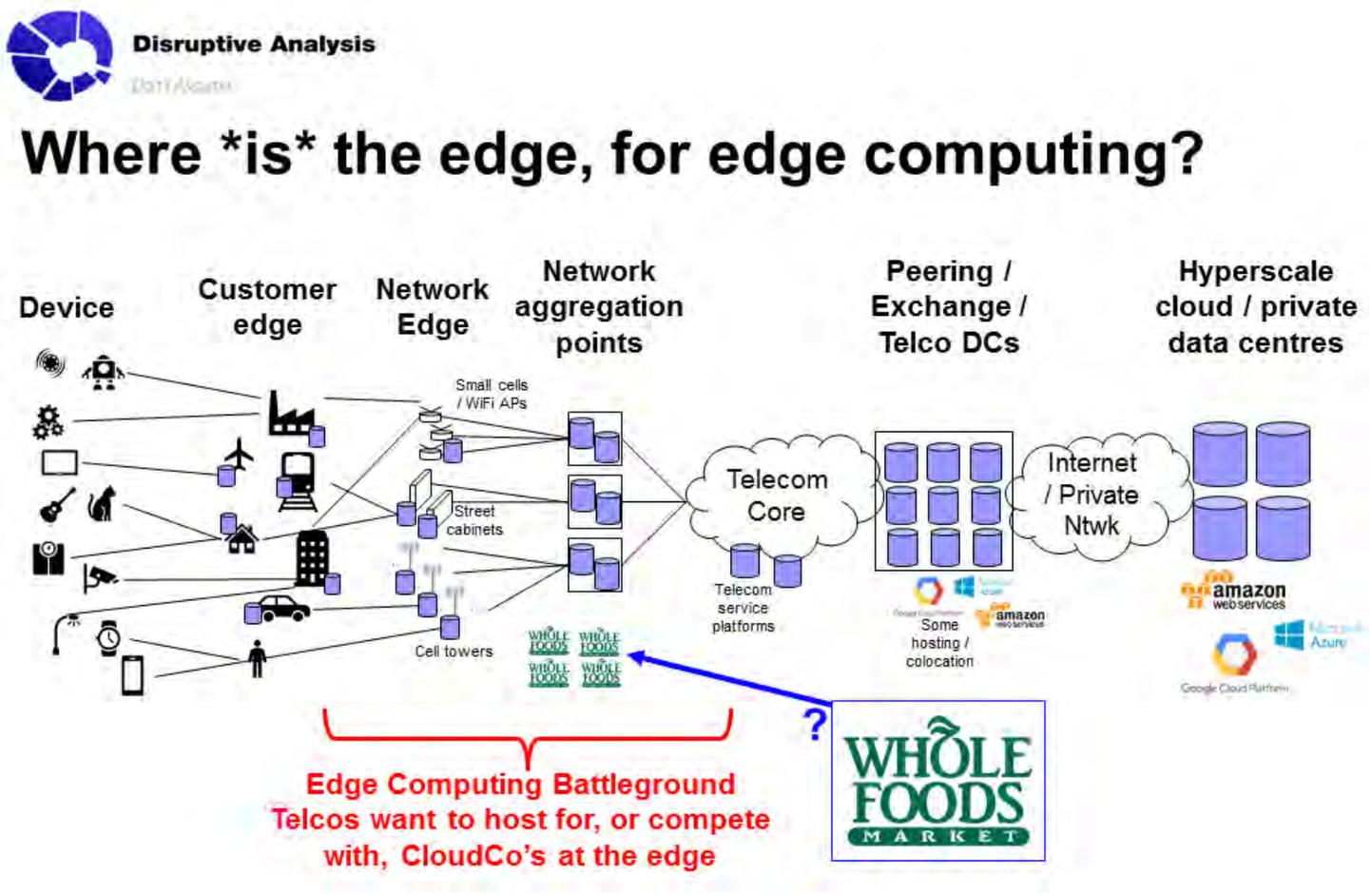
Connected Cars and Smart Cities

From: Tao Zhang, Cisco Distinguished Engineer, Co-Founder and Board Director of OpenFog Consortium



There may be many “edges” in the “fog”

- 5G is intimately tied to the Internet and other communications
- More layers of connectivity are envisioned with IoT devices resulting in multiple ”edge” connectivity and possibly data storage and processing
- Eluvio introduced the concept of a content fabric that uses blockchain authenticated peer to peer delivery of content versus today’s highly centralized Content Delivery Networks (CDNs).



EXAMPLE - CDN VS CONTENT FABRIC

LIVE STREAM

8 versions / edits
3 formats
5 bitrates (4 sec seg) = 19.85 MB / seg

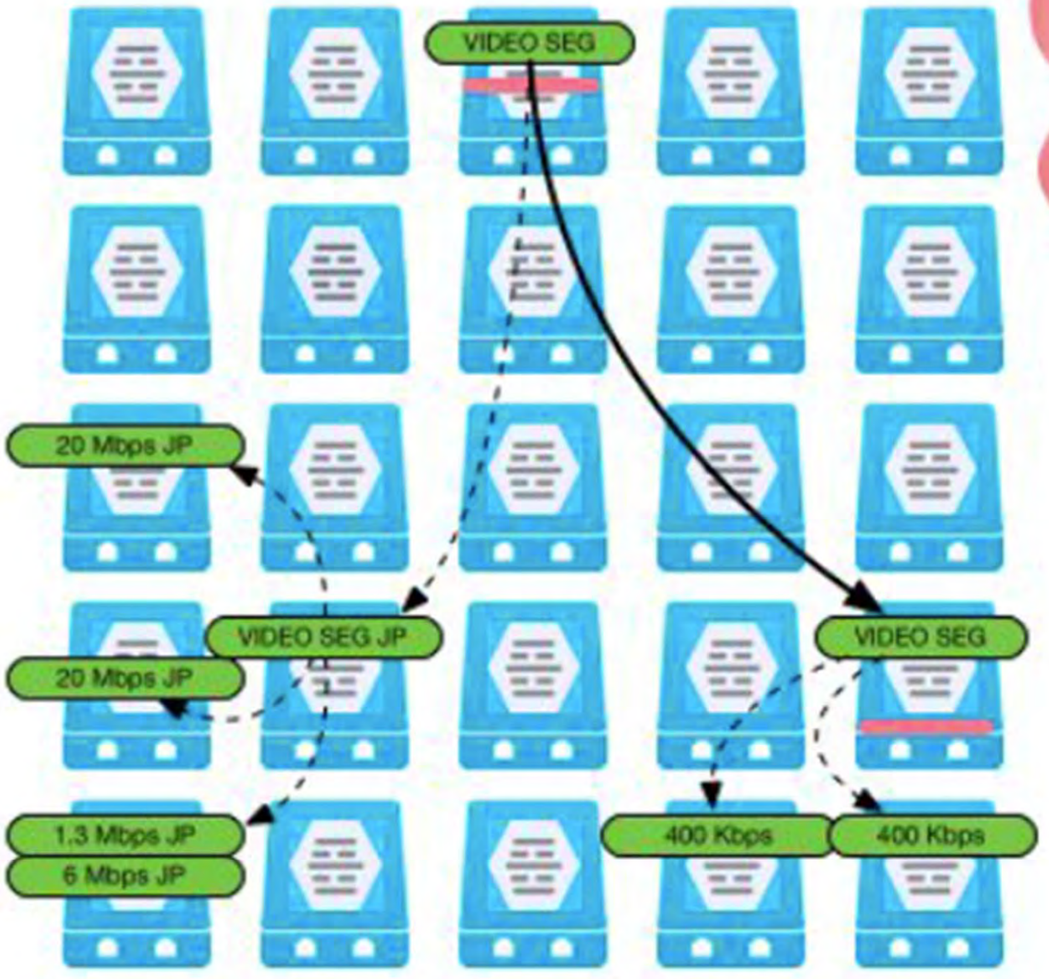
Master - 12 MB
20 Mbps - 10 MB
12 Mbps - 6 MB
6 Mbps - 3 MB
1.3 Mbps - 650 KB
400 Kbps - 200 KB

ALL BITRATES = 19.85 MB

TYPICAL CDN PUSH

8 x 3 x 19.85 MB = 476.4 MB per segment

900 segments per 1 h stream ==>
428.76 GB per 1h stream



MANY BITRATES IN REGION
(example: Japan)

only one version/edit
only push master

1 x 3 x 12 MB
36 MB per segment
32.4 GB per stream

13x reduction

SINGLE BIT RATE REGION
(example: India mobile)

only two versions/edits
only push low bw

2 x 3 x 850 KB
5.1 MB per segment
4.59 GB per stream

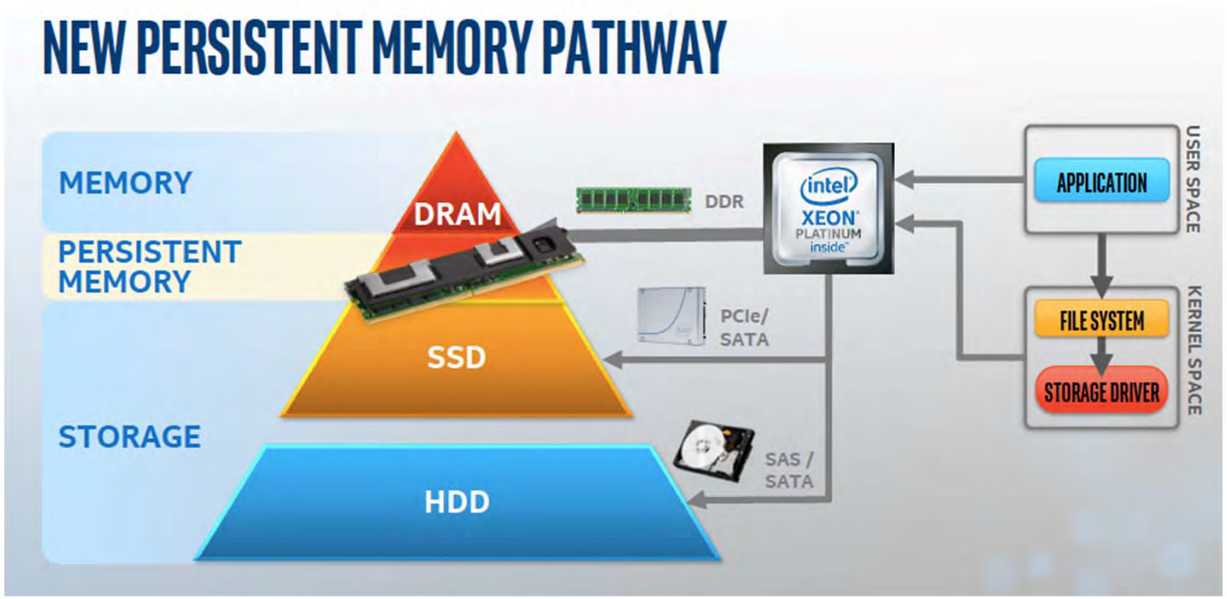
93x reduction

Michelle Munson, Eluvio presentation at the 2018 Creative Storage Conference (www.creativestorage.org)

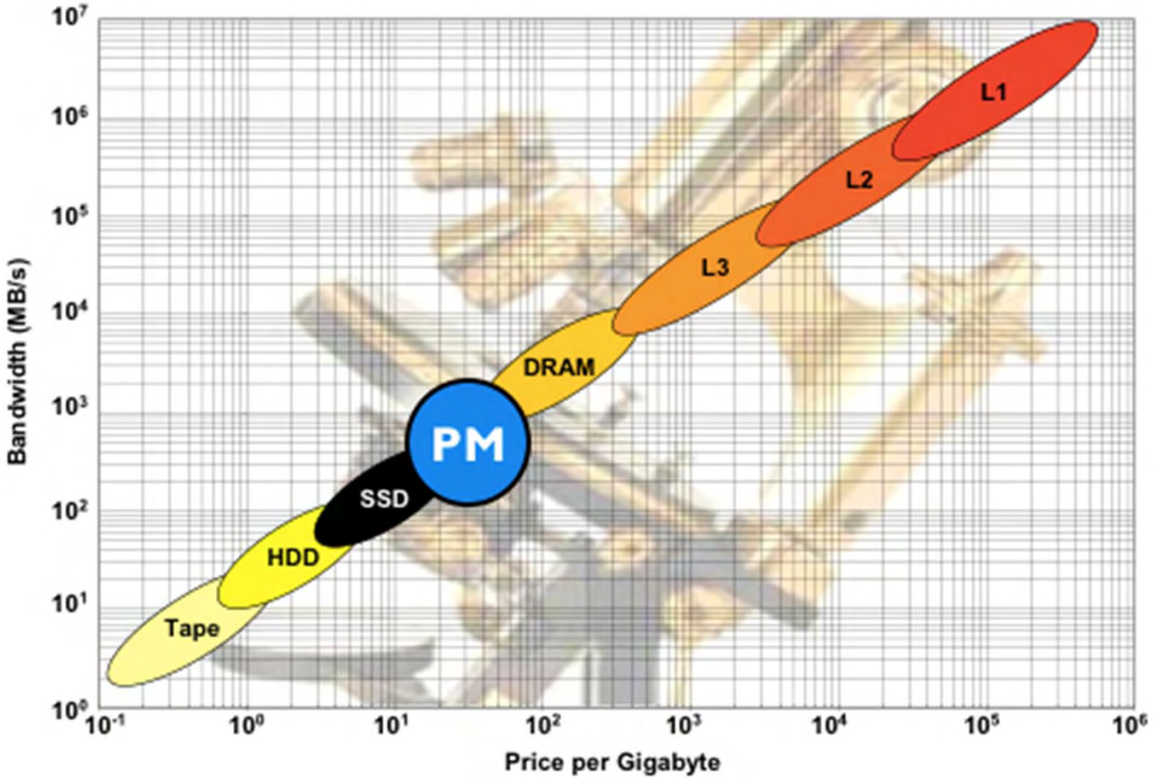
Investments in infrastructure

- Faster data delivery speeds need faster equipment behind the radio delivery system
- Lower latency requirements will drive requirements for communication, processing and storage at the ”edge.”
- Changes to new distribution models, such as Eluvio’s Content Fabric could change the nature of local connection nodes, including storage, processing and communication requirements
- In particular local content rendering, content caching and buffering will be key components in providing good content QoS
- This will lead to new investments in storage/memory architectures to support new ways to access, process and capture content and data

Digital Storage and Memory Tiering

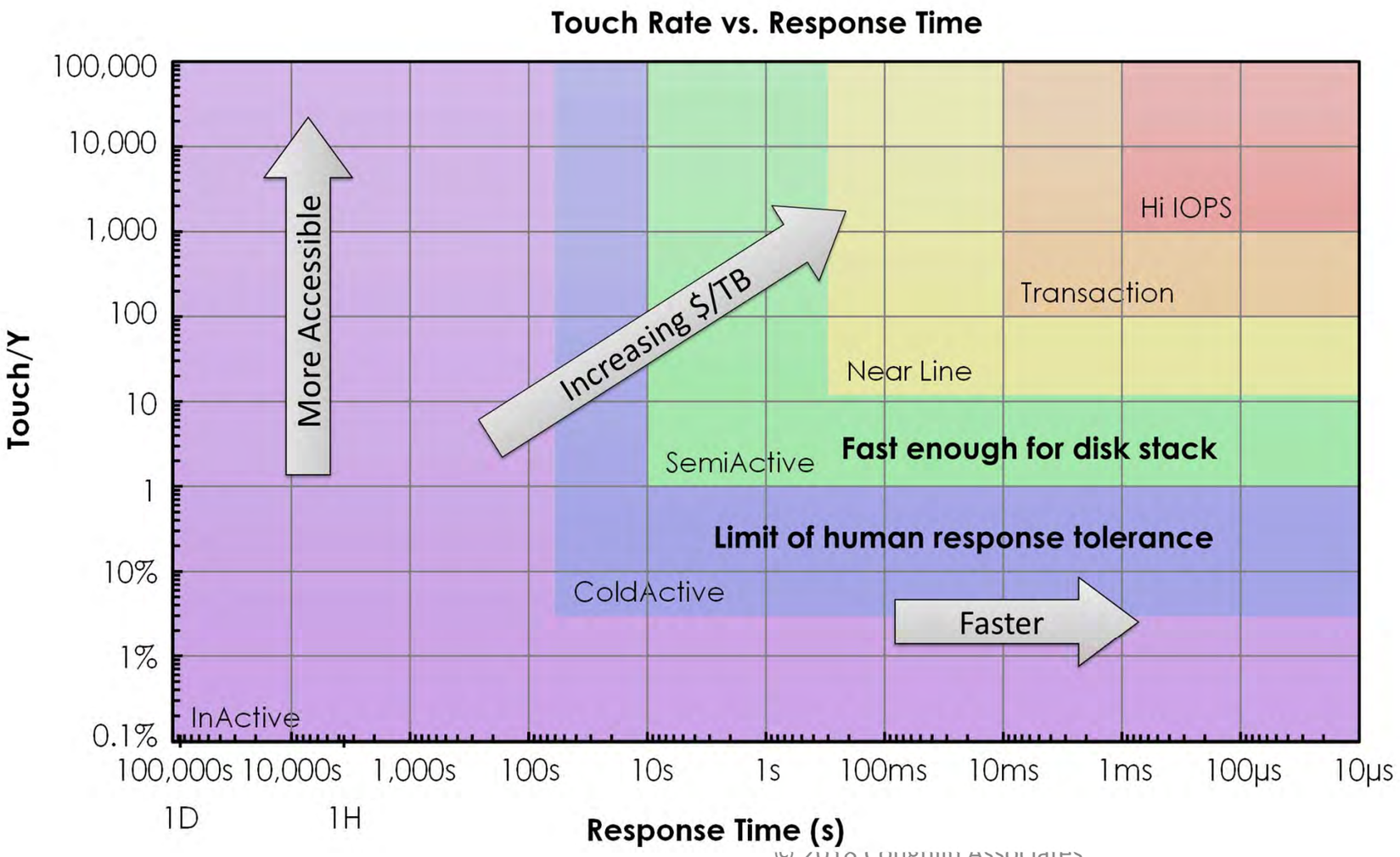


Intel Optane DIMM Announcement, June 2018



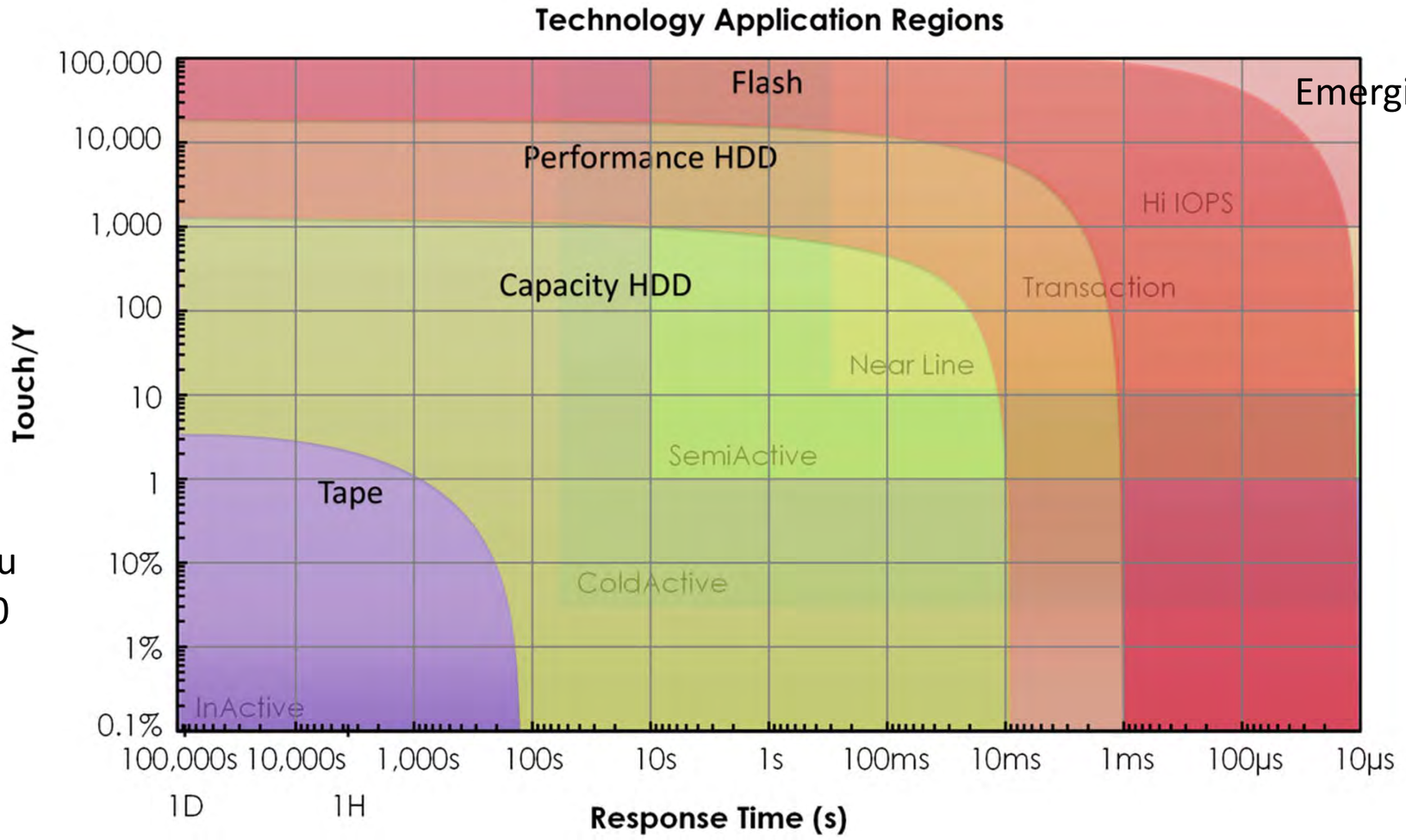
2018 Emerging Memories Report, Coughlin Associates, www.tomcoughlin.com

Touch rate versus response time indicating various types of uses



https://tomcoughlin.com/Coughlin/Techpapers/Hetzler%20Paper/Touch%20Rate.pdf

Digital storage technologies regions overlaid on the Touch Rate/Response Time chart



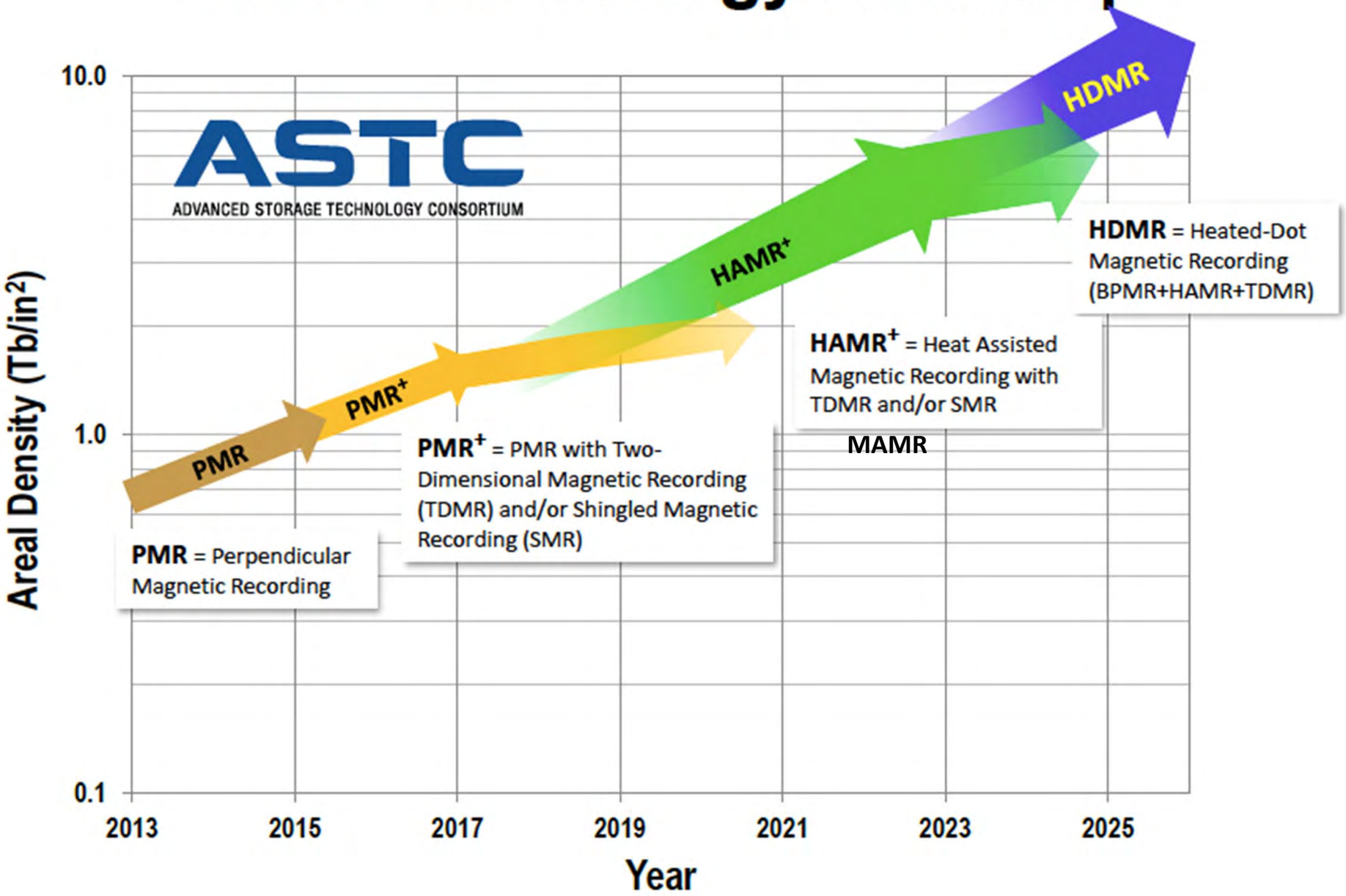
Emerging Memories

https://tomcoughlin.com/Coughlin/Techpapers/Hetzler%20Paper/Touch%20Rate.pdf

Hard Disk Drives

- Currently shipping up to 14 TB with 20 + TB expected by 2019, 40 + TB by next decade
- Current HDD areal densities exceed 1 Gb per square inch
- He-filled HDDs provide greater energy efficiency and less cooling requirements
- Fastest growth in HDDs is for bulk cold storage in data centers
- Besides magnetic tape and optical discs, HDDs are the most cost effective storage medium for colder data

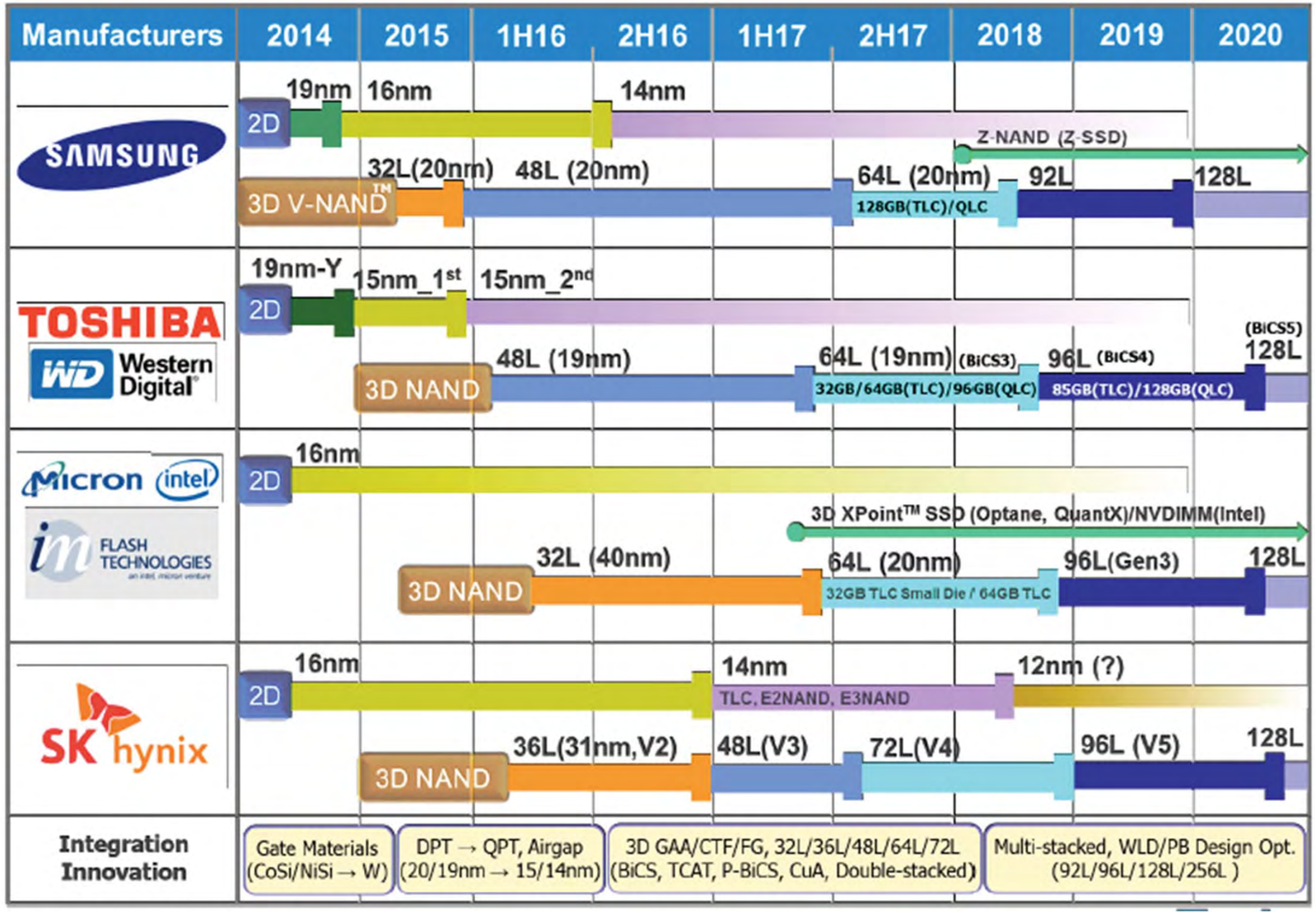
ASTC Technology Roadmap



Flash Memory

- Flash memory is increasing in storage capacity (density) and decreasing in $/GB pricing but still more expensive than HDDs
- Flash memory is winning more applications as its price ($/GB) drops
- Development of NVMe and NVMe-oF has enabled better access to the performance capabilities of flash memory
- In many data center applications, flash memory is now the primary storage
- Flash Memory can also handle more rugged environments, making this a favored storage media for remote location—such as for edge storage

Flash memory roadmap



Emerging Non-Volatile Memories

- There is intense effort to commercialize several non-volatile memories that could replace current volatile memories, such as DRAM and SRAM
- These technologies can be applied to stand along memory chips as well as in embedded memory
- This could reduce energy expenditure in battery and low power devices and also create more efficient data centers
- These NV memories will enable both IoT devices as well as data centers at the edge or in the cloud
- The memory technologies under consideration include magnetic random access memory (MRAM), resistive RAM (RRAM or ReRAM), phase change RAM (PRAM) and ferroelectric RAM (FRAM or FeRAM)

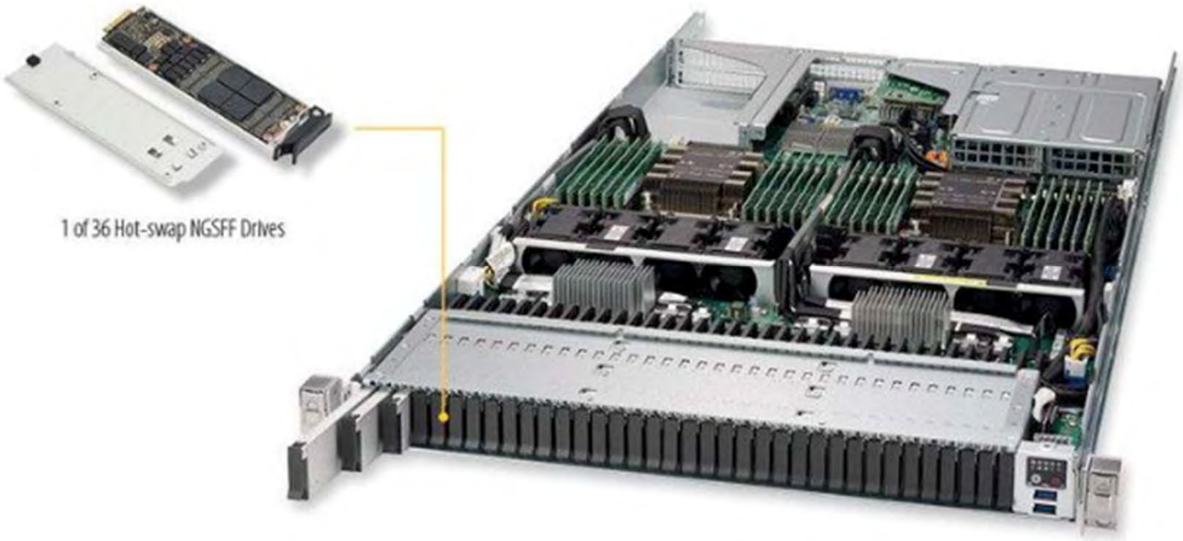
Memory Technology Comparison

Technology	FeRAM	MRAM	ReRAM	PCM	DRAM	NAND Flash
Nonvolatile	Yes	Yes	Yes	Yes	No	Yes
Endurance	10^{12}	10^{12}	10^{6}	10^{8}	10^{15}	10^{3}
Write Time	100ns	~10ns	~50ns	~75ns	10ns	10µs
Read Time	70ns	10ns	10ns	20ns	10ns	25µs
Power Consumption	Low	Medium/Low	Low	Medium	Very High	Very High
Cell Size (f^2)	15-20	6-12	6-12	1-4	6-10	4
Cost ($/Gb)	$10/Gb	$30-70/Gb	Currently High	$0.16/Gb	$0.6/Gb	$0.03/Gb

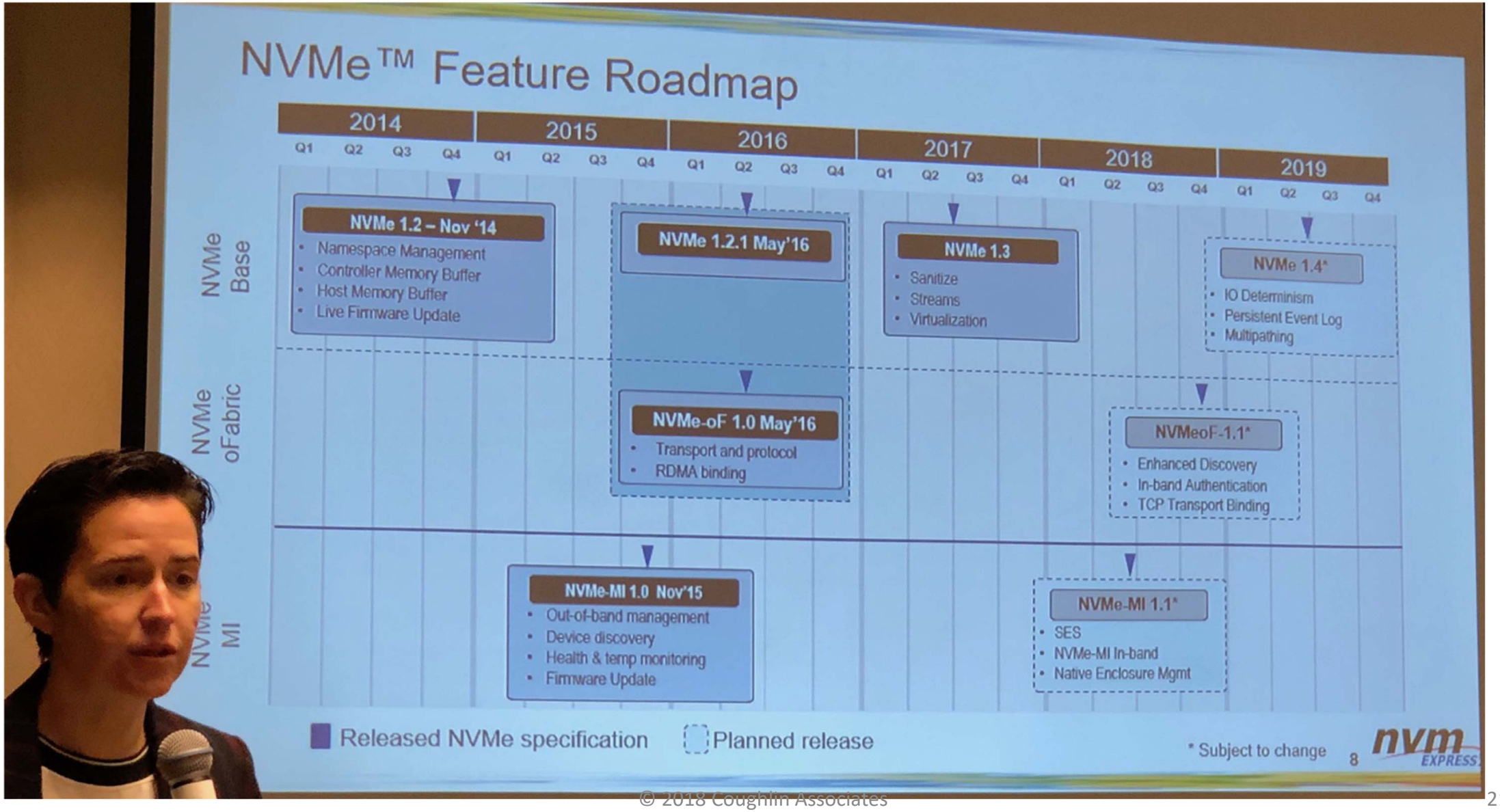
How Persistent Memory will Success, Tom Coughlin and Jim Handy, 2018 SNIA Persistent Memory Summit, January 2018

Storage Systems for Edge and Data Center

- PCIe based NVMe storage interfaces will be the basis of future storage systems architectures using flash-based solid state drives
- This includes network storage capabilities including Remote Direct Memory Access (RDMA) and fabrics running the NVMe protocol, NVMe-oF

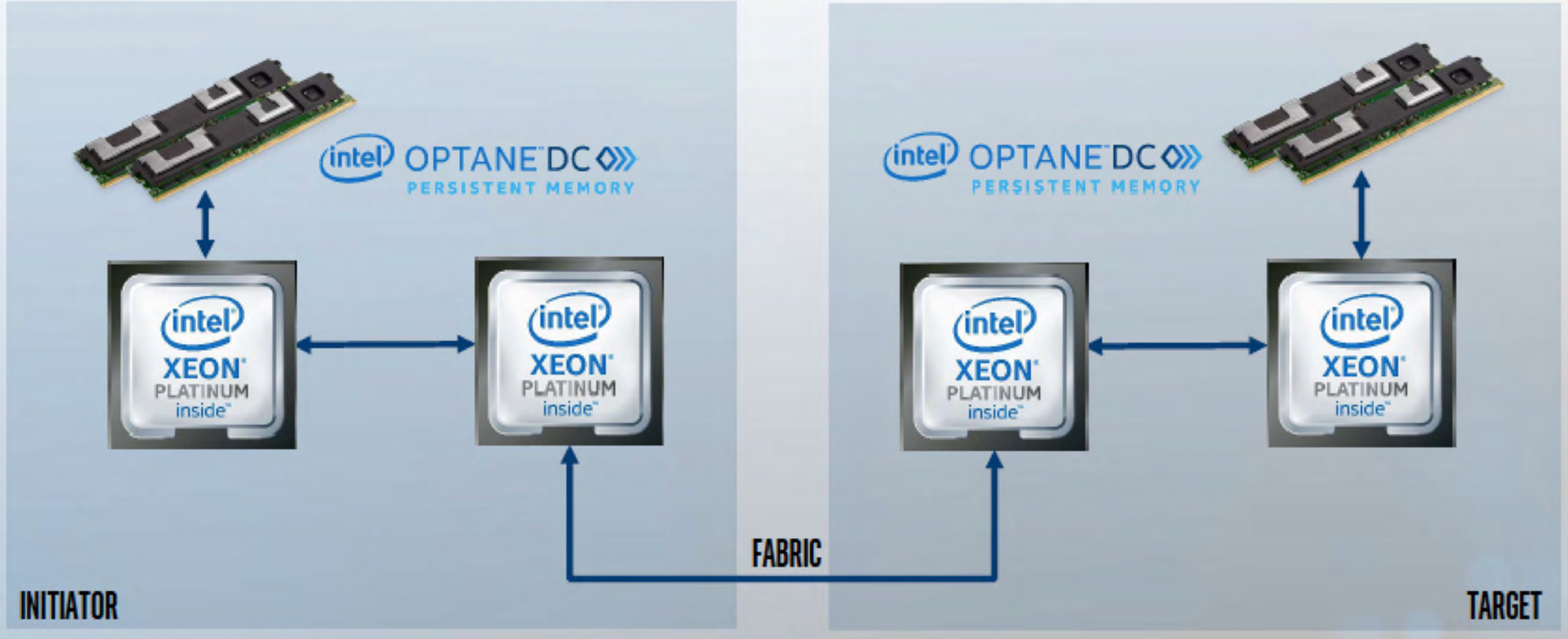


NVMe Architectures and DIMMS



PERSISTENT MEMORY OVER FABRICS (PMoF)

FOR DATA REPLICATION WITH DIRECT LOAD/STORE ACCESS



Storage Systems for Edge and Data Center (2)

- Solid state storage using server memory channels (DIMMs) will be the basis of non-volatile memory using flash memory and emerging technologies, such as Intel's Optane
- HDD object storage will be the backbone to mass storage for colder storage (behind solid state primary storage)
- Tape (or optical discs) may be used for longer term colder data

Conclusions

- 5G will be a factor in the growth of digital content over the next decade and will increase requirements for more digital storage and memory solutions throughout the 5G network
- This could include real time rendering, buffering and caching solutions to improve content delivery QoS, perhaps using a peer to peer network
- The demand for lower latency will drive the use of solid state storage as primary storage in data centers and at the network edge
- New storage technologies and architectures as well as traditional storage technologies will enable 5G deployments

References

- The Memory of Cars, Tom Coughlin, https://ieeetv.ieee.org/ieee-local-events/the-memory-of-cars-talk-by-tom-coughlin
- Michelle Munson, Eluvio presentation at the 2018 Creative Storage Conference (www.creativestorage.org)
- https://tomcoughlin.com/Coughlin/Techpapers/Hetzler%20Paper/Touch%20Rate.pdf
- How Persistent Memory will Success, Tom Coughlin and Jim Handy, 2018 SNIA Persistent Memory Summit, January 2018
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Thanks!