PCIe/NVMe in Mobile Devices

Better Storage Enables Better Mobile Devices

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Forward Looking Statements

During our meeting today, we may make forward-looking statements.

Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to market position, market growth, product sales, industry trends, supply chain, future memory technology, production capacity, production costs, technology transitions, construction schedules, production starts, and future products. This presentation contains information from third parties, which reflect their projections as of the date of issuance. Actual results may differ materially from those expressed in these forward-looking statements due to factors detailed under the caption “Risk Factors” and elsewhere in the documents we file from time to time with the SEC, including our annual and quarterly reports. We undertake no obligation to update these forward-looking statements, which speak only as of the date hereof or the date of issuance by a third party, as the case may be.

- Tablet or Laptop?
- ARM or x86?
- Windows / Android?
- Mobile?

Client Platforms Convergence

- Smart client device segments converging/blurring
- Mobile platforms are computing platforms
  - Content creation / productivity is the key differentiation today
- Computing platforms become truly mobile

Storage Solutions in Smart Client Devices Current View

e.MCP

eMMC

SATA

PCIe/NVMe

Budget Smart Phone

Entry Level Tablet

Flagship Smart Phone

Phablet

Chrome Book

Productivity Tablets

2-in-1's

Entry-Level PC HDD Replacement

Mainstream PC

High-End PC

Client-Grade Server & Workstation

Alternatives for Future Storage Solutions in Mobile

- Extend eMMC
  - HS400 → HS533 → HS667
- UFS
- PCIe/NVMe

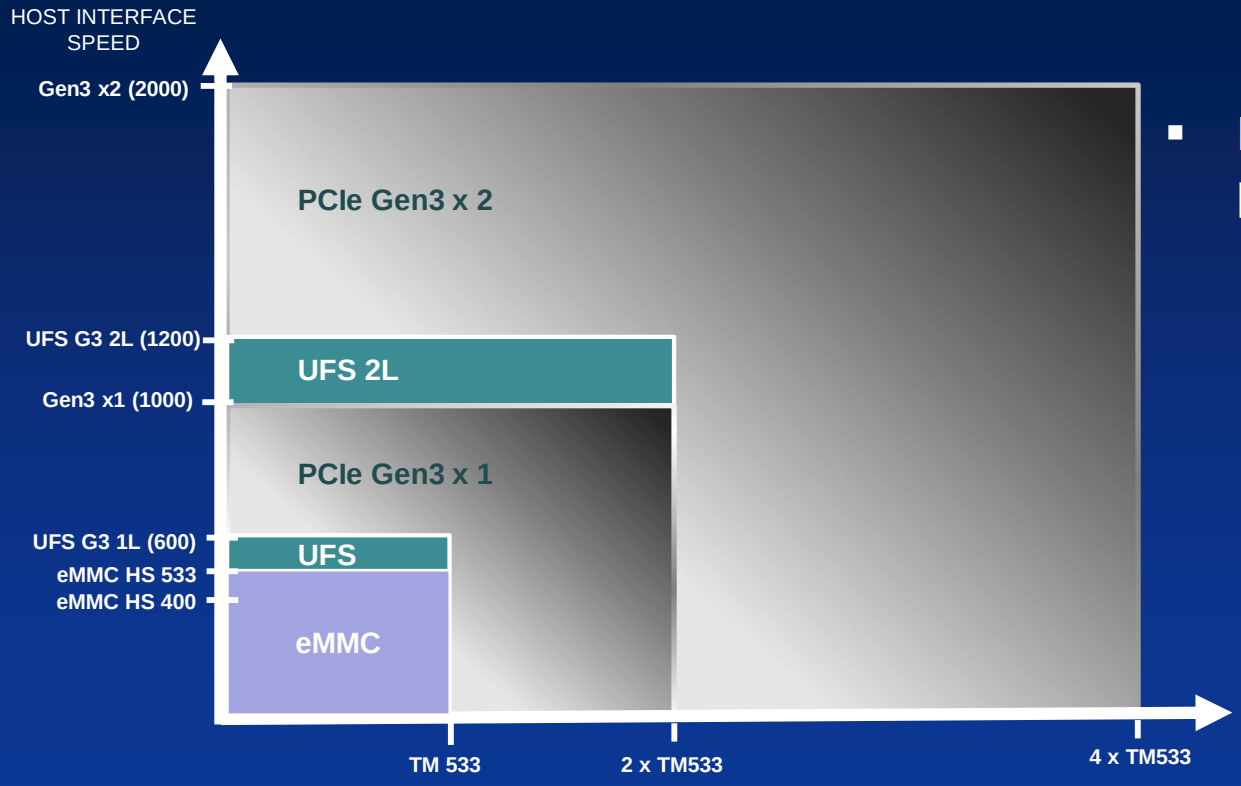
PCIe is The Future of Mobile Storage

- Key advantages of PCIe/NVMe
  - Bandwidth and scalability
  - Availability, compatibility
  - Lowest latency SW stack
  - Simplicity
  - Smart architecture & design

Technical Comparison

	Item	eMMC	UFS 2.0	PCIe/NVMe	PCIe/NVMe
Phy/link	**Interface**	HS400→HS533	M-Phy Gear 3	Gen2	Gen3
	Bus speed MB/s	400 → 533	583	500	1000
	PHY overhead	N/A	8/10	8/10	128/130
	Pin Requirements	10	6 (per lane)	8	8
HW	**Architecture**	Master-Slave Host controller	Master-Slave Host controller	Smart device – Bus Master	Smart device – Bus Master
	Host Memory Buffer	N/A	Complex (UMA)	Native	Native
SW	**Protocol Complexity**	eMMC - simple	SCSI + UFS Complex	NVMe Simple	NVMe Simple
	Overhead	High	High	Low	Low
	Queue architecture	Single queue	Single queue	Multi queue	Multi queue

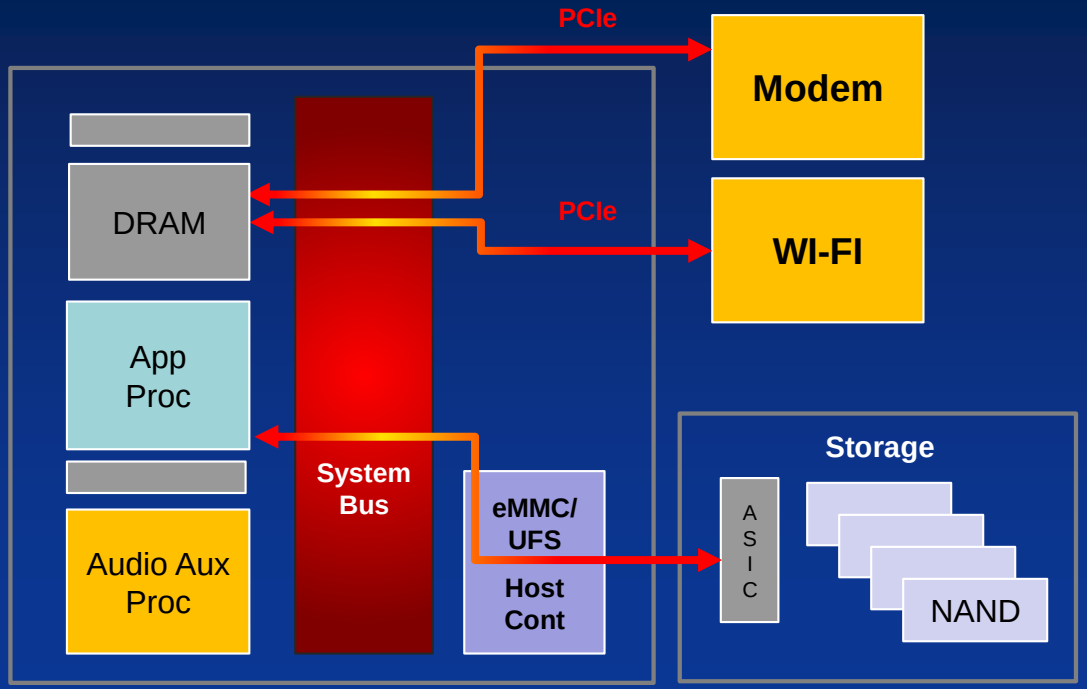
Interfaces Scaling Path



- PCIe has the best scaling path for Mobile applications
  - 1GB/s in single lane
  - Growth up to 2GB/s

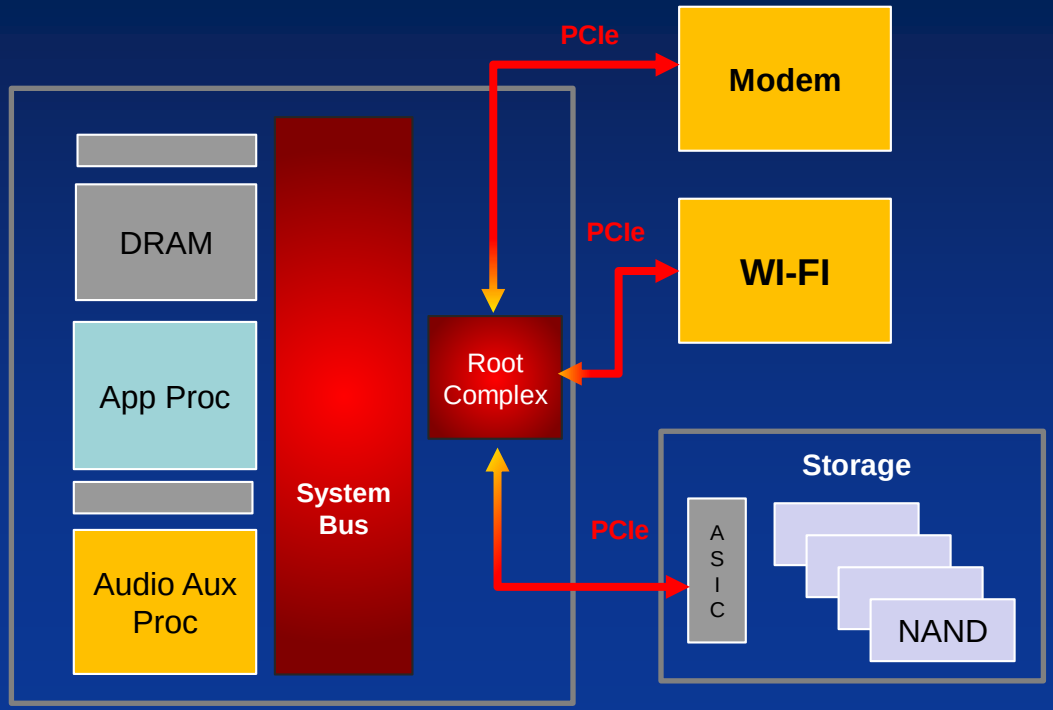
PCIe is in Mobile Today

- **PCIe used for connectivity today**
- Storage - data transactions manage by AP & host controller
- No direct connection between sub systems and storage

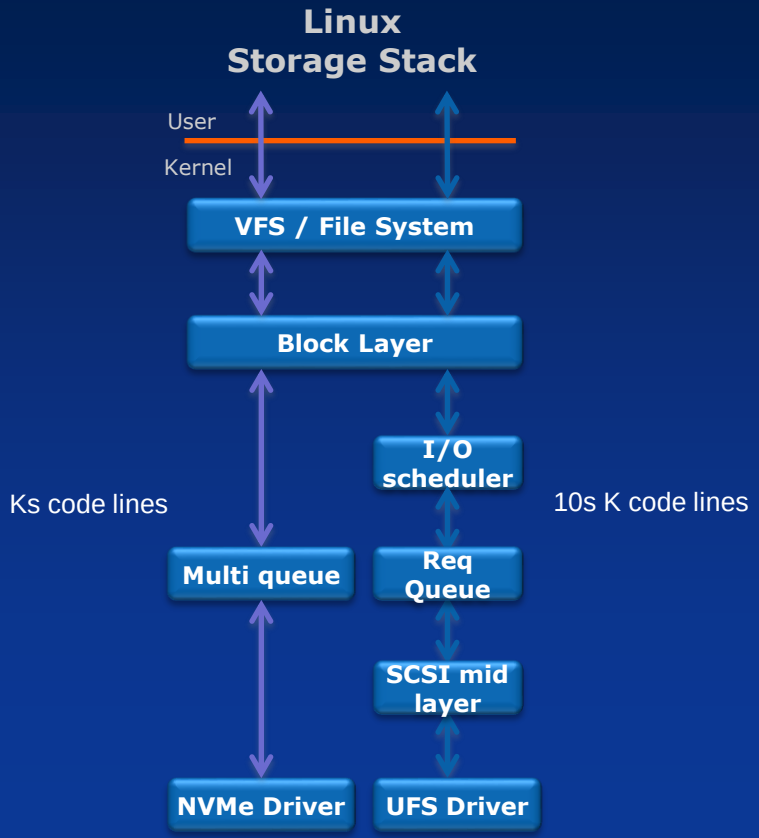


Smart Devices Architecture

- ***Fastest*** download/ upload speeds
  - Efficient data transfer paths
- ***Lowest*** power architecture
- Minimize AP involvement in transactions



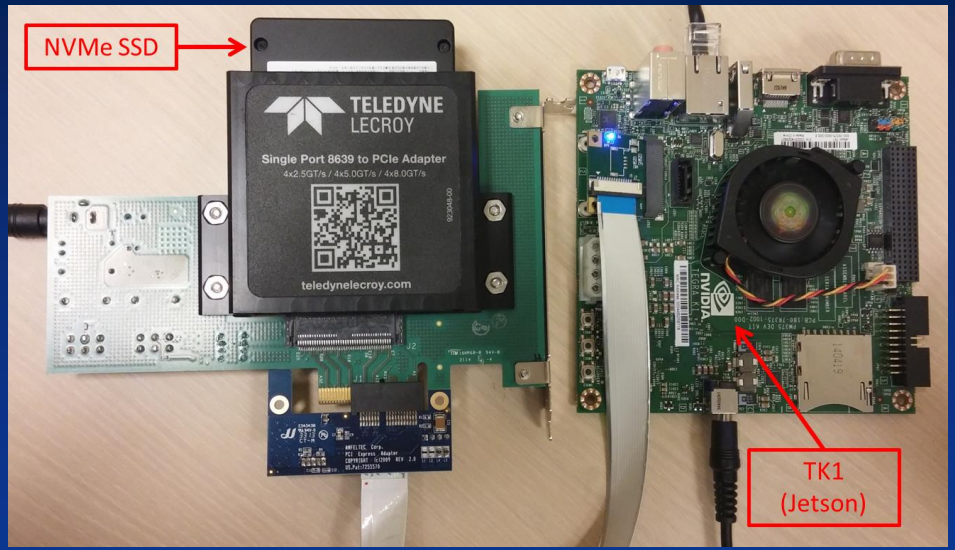
NVMe has Superior SW Stack



- Low Latency
  - Efficient driver stack
  - Short code paths
- Supports parallelism in platform
  - Mobile SoC are quad core today, and increasing
  - Increasing multitasking in Mobile
- Simple stack
  - Supportability
  - Easier development

Enabling NVMe on ARM/Linux

- NVMe is part of standard Linux Kernel
- NVIDIA TK1 reference Platform (ARM, PCIe port)
- NVMe SSD immediately enabled with open source driver

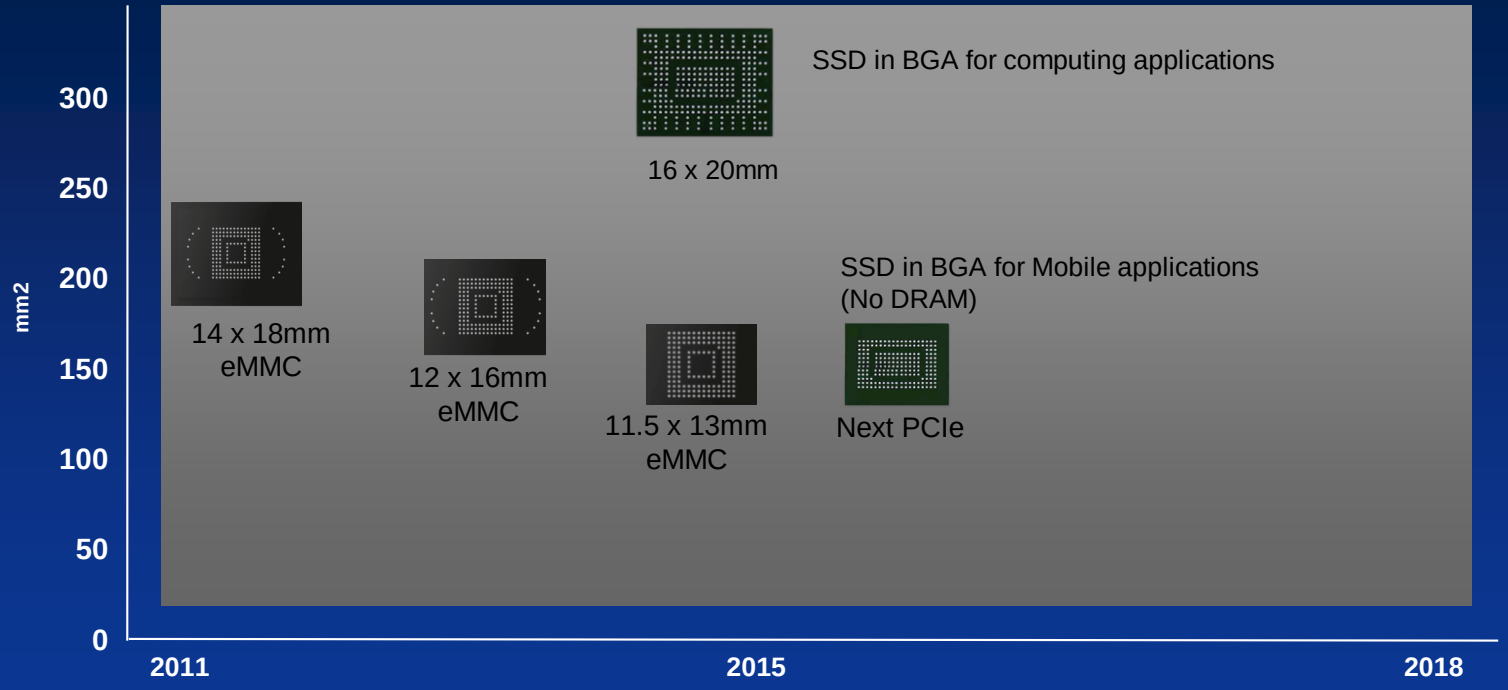


*SanDisk internal development system based on NVIDIA reference design

Enabling PCIe/NVMe for Mobile

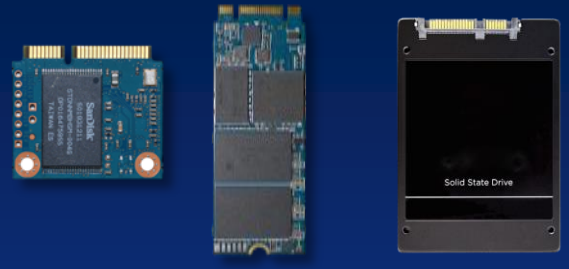
- Define small package for Mobile
- NVMe: ROM based boot scheme

Storage Solutions in BGAs



DRAM-less PCIe/NVMe SSDs can be packaged in 11.5 x 13mm

Storage Solutions in Smart Client Devices Future Vision



e.MCP | eMMC | PCIe/NVMe | PCIe/NVMe | PCIe/NVMe

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Summary

- The best evolution for Mobile storage is PCIe/NVMe
  - Leverage the investments in client compute platforms
  - Consolidation of storage solutions
  - NVMe superiority over SCSI
  - PCIe scalability
  - PCIe bus architecture
  - PCIe exists in Mobile platform today
- Impact beyond storage – better SoC design

Thank You

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