3-D NAND and UFS

Innovation ACCELERAT3D #InnovationAccelerated

Optimized Mobile Storage

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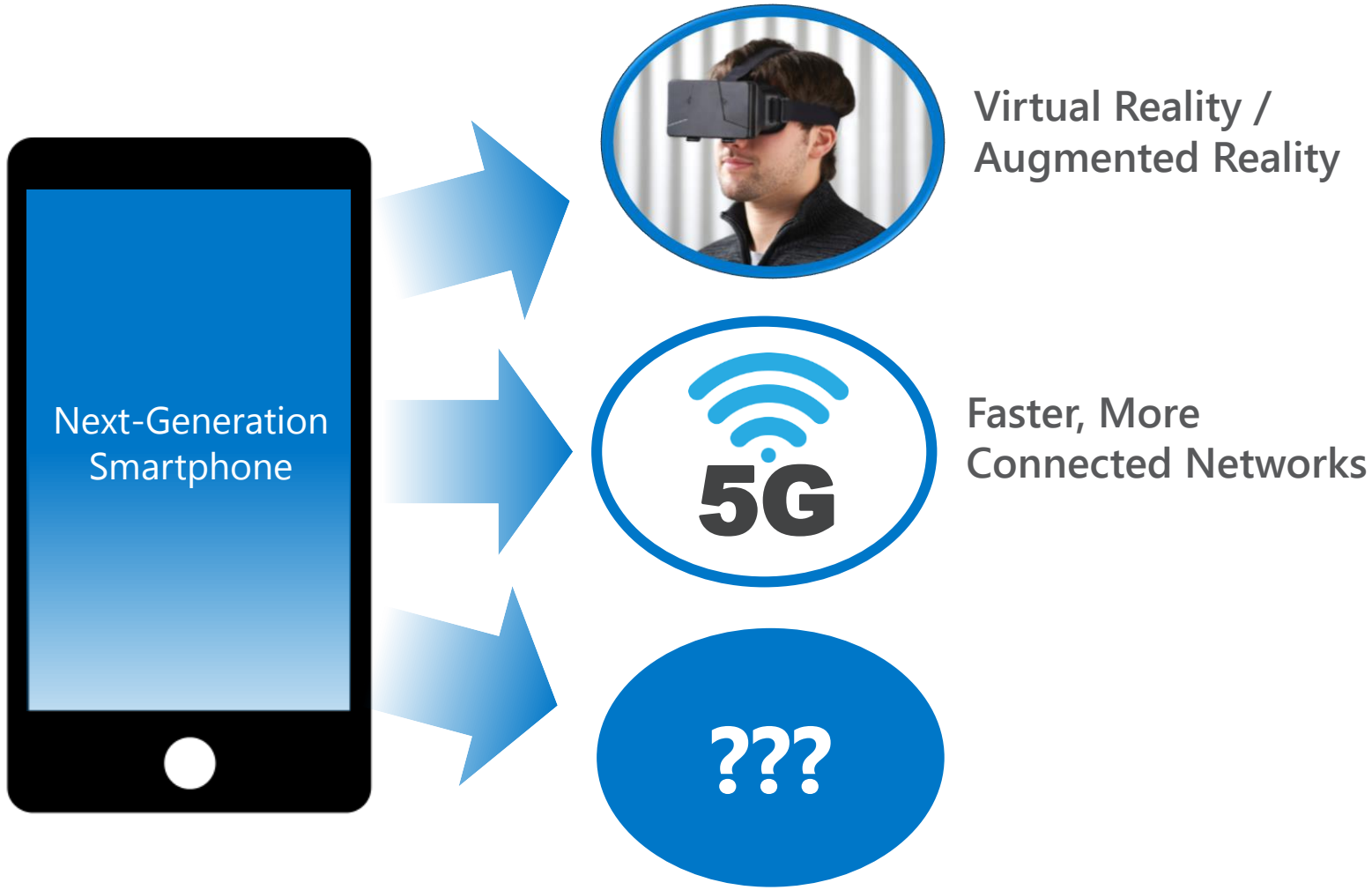
The Future of Mobile



Virtual Reality / Augmented Reality

Faster, More Connected Networks

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Overview

- Mobile consumes a huge amount of Memory & Flash
- UFS and the Mobile Ecosystem
- 3D NAND in Mobile

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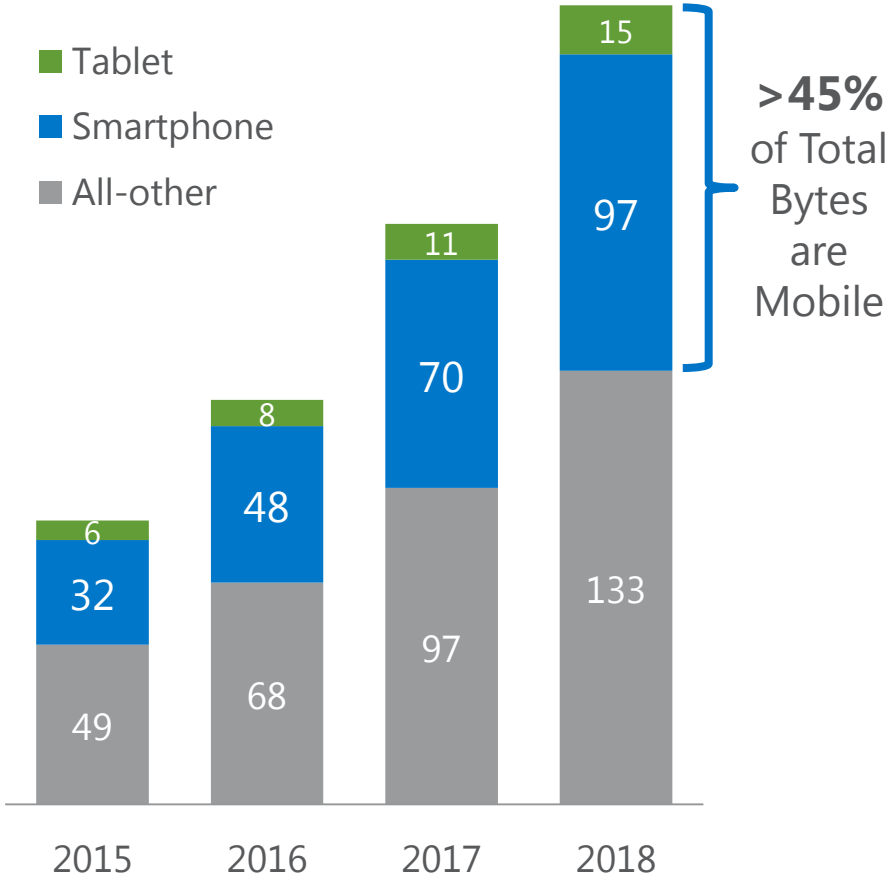
Mobile Market Flash Outlook

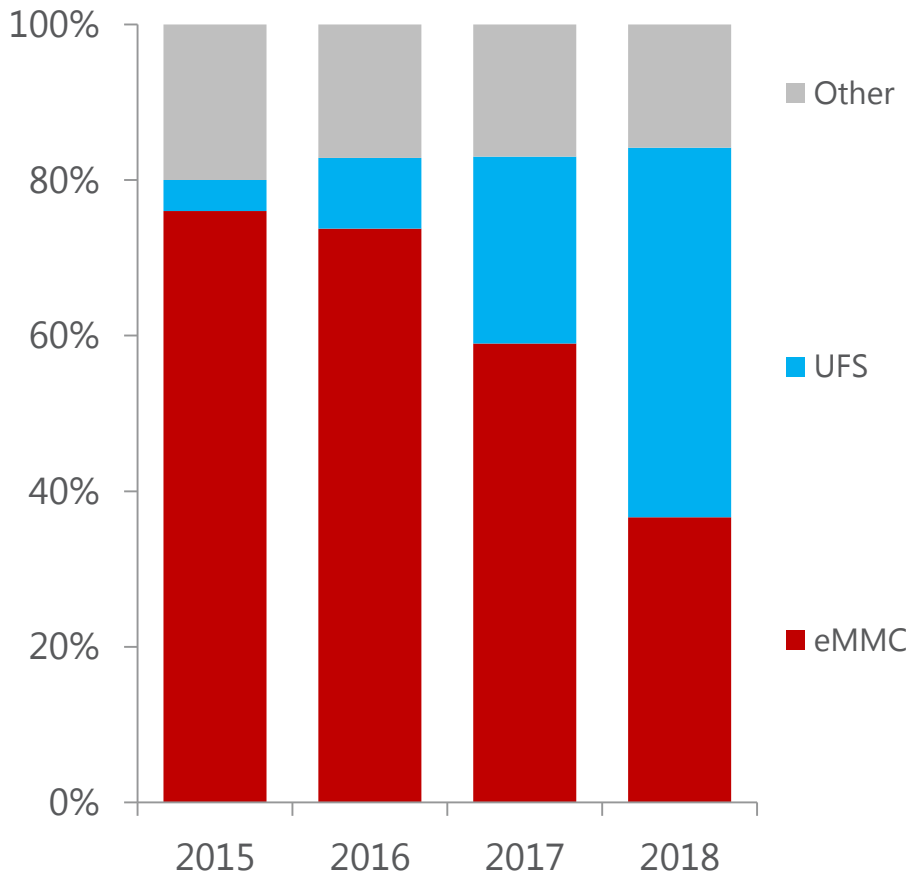
NAND Bit Demand

Billion of GB Equivalent



Mix of Mobile Memory interface (%)

By Unit Shipment



Source: MBU Strategic Marketing

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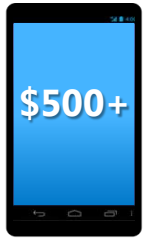
Mobile Breakdown by Segment

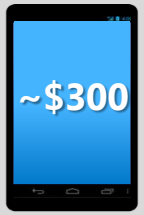
Flagship



‘Feature’ differentiation

- 64bit Processing; 4-6GB LP4/4x
- Dual Lens Cameras
- VR Headset Compatibility
- 32-128GB UFS v2.1 G3x1L/2L

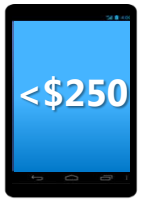
High/Mid End



‘Specification’ differentiation

- 32bit Processing; 3-4GB LP3/4x
- MCP and Discrete/PoP Mix
- 16-64GB eMMC v5.1/UFS v2.1 G3x1L

Low End



‘Cost’ differentiation

- Reduced features and hardware spec
- ~3 months time to market
- 1-2GB LP2/3 + 8/16GB eMMC (MCP)

UFS Market Adoption

‘15-’16
5+
Chipsets

2017
3+
Chipsets

2018?

*Un-subsidized Retail Price. Low-end models usually sold at a higher discount.

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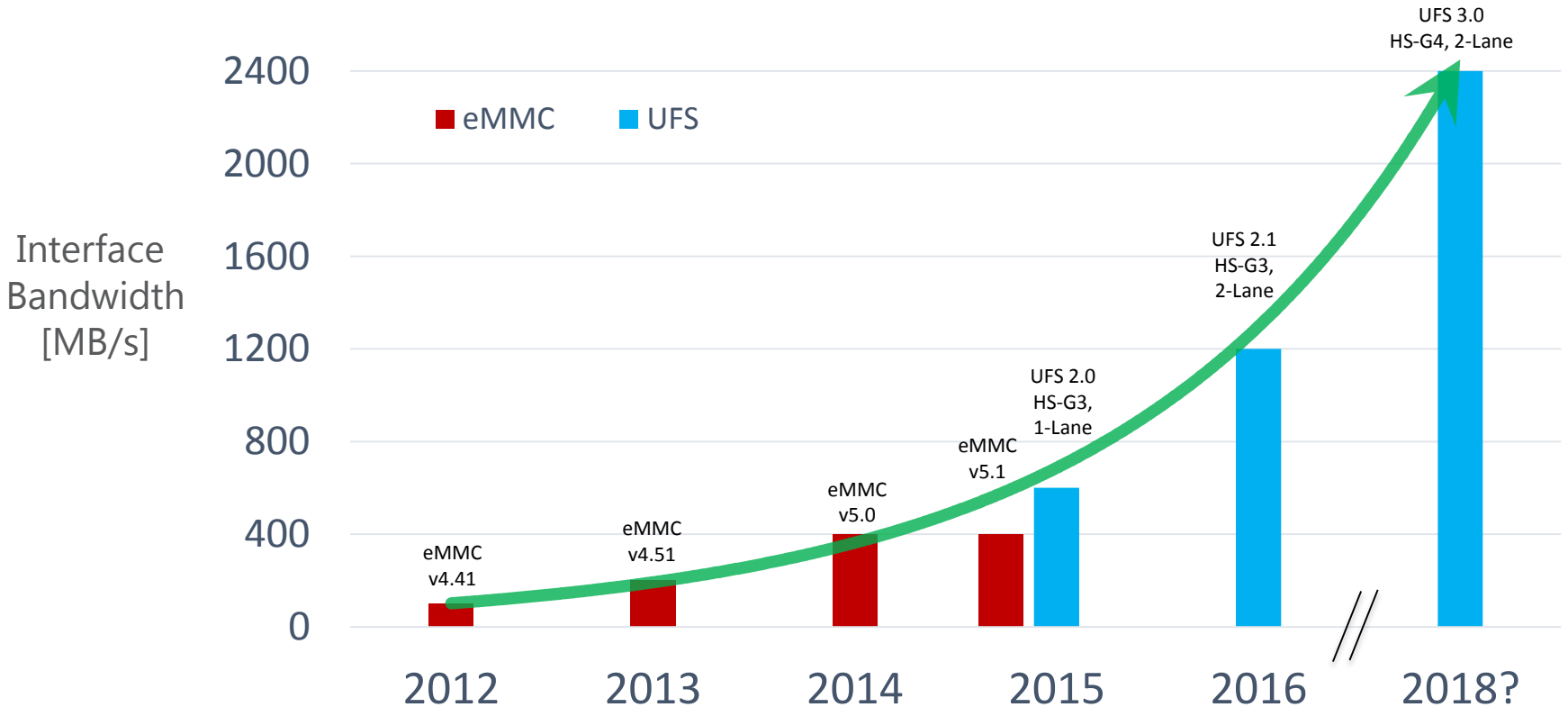
Next-Gen Mobile Performance Scaling



Future Performance Scaling

- UFS Interface allows for ***Bandwidth Growth*** needed for Next-Gen Mobile
- Serial high-speed interface is ***scalable*** for faster speeds & Multi-Lane Support
- Full-duplexing for ***simultaneous*** Read/Write mixed-mode operation
- Mobile Storage Interface no longer a bottleneck!

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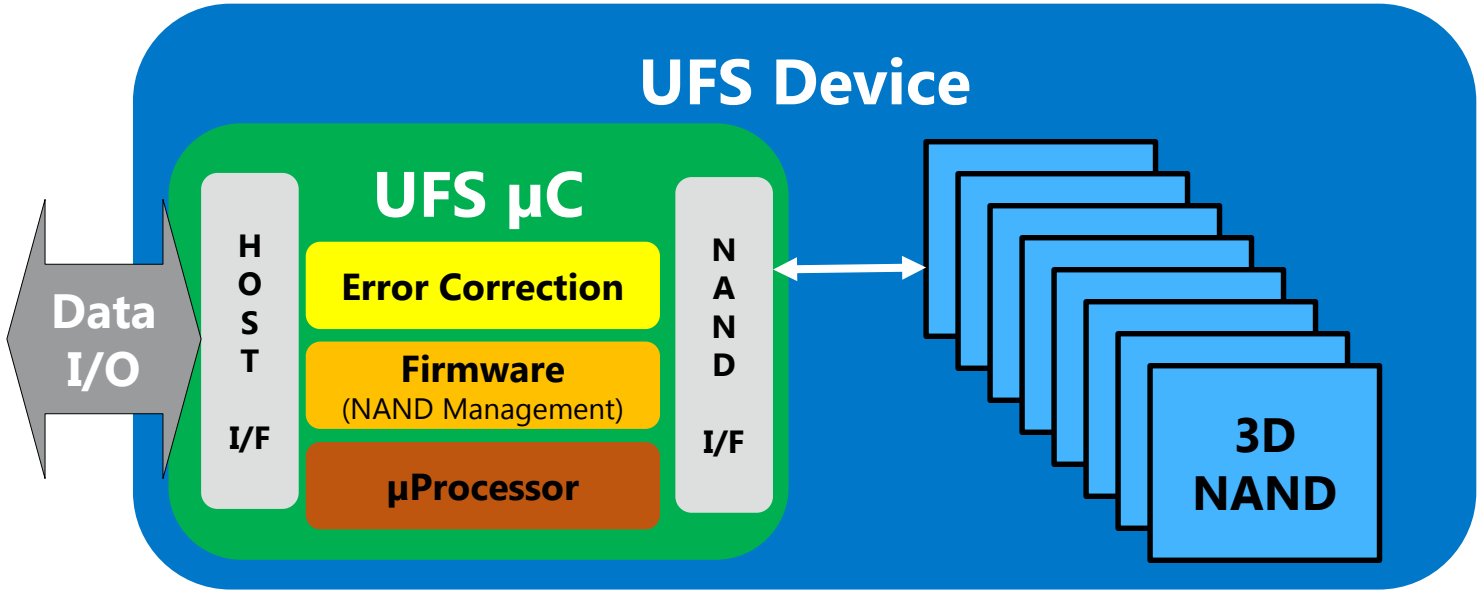
Optimal Performance Requires a System-Level Approach

Host I/O
Performance scales by speed selection and up to 2 Lanes



NAND Media
Performance scales with # of die (to Max I/O bandwidth)

Typically 8 die Max due to packaging and cost limitations

3D NAND offers numerous advantages:
- Faster R/W performance
- Density Scaling
- Higher power efficiency and lower sleep power
- Increased Reliability

UFS Controller
Blocks scaled to deliver desired performance within cost and power budget

UFS Firmware
Increased efficiency to deliver consistently high performance

NAND I/O
Performance scales with # of channels and interface speed

- Bandwidth increasing 533MT/s → 667MT/s → 800MT/s

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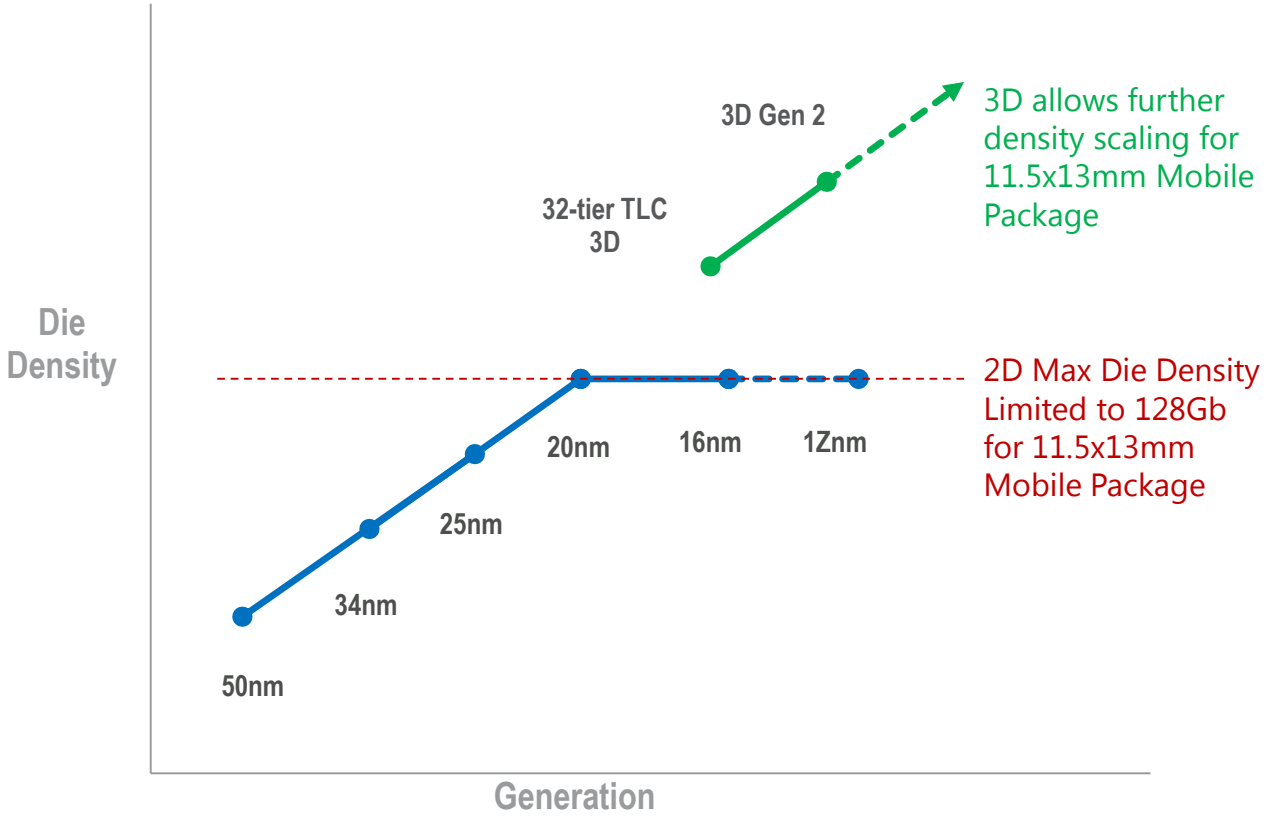
3D NAND Scaling Advantages

- Density Scaling
  - Higher Densities in Mobile packages
  - Lower cost per Byte
- Increased Reliability
  - Larger Cell Size stores more electrons per state
    - Faster Performance
    - Improved Endurance
    - Superior Data Retention



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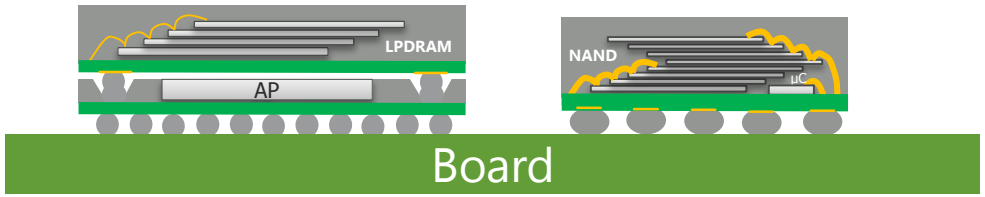
Mobile Packaging and 3D NAND

Higher densities made possible using 3D NAND

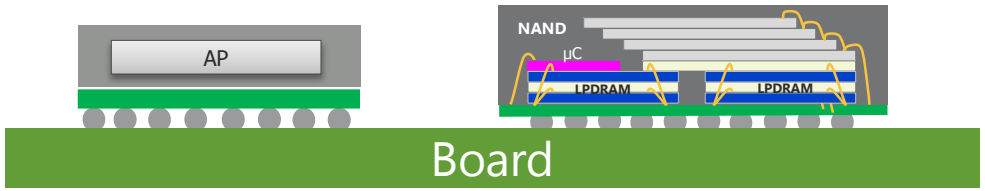
Flagship / High-End

- PoP Configuration (App. Processor + LPDDR)
- Standalone UFS – typically up to 8-die stack
  - 128GB growing to 256GB and up



Mid- / Low-End

- Standalone Application Processor
- MCP – Managed NAND + LPDDR
  - Up to 128GB UFS + 6GB LP possible



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Micron Mobile UFS 3D NAND Memory

Breakthrough storage performance, power and reliability

High Performance

~30% faster sequential writes vs. 2D NAND; UFS 2.1 interface delivers 33% higher bandwidth vs. e.MMC 5.1

Enhanced Reliability

Unique floating gate technology provides superior data retention compared to charge trap gates

Power Efficiency

Significantly reduce power with 3D NAND's efficient sleep mode feature

Superior Mobile Experience

Faster boot up, seamless HD streaming, high bandwidth gaming, and responsive camera performance

High Capacity

Higher storage capacity in a smaller space with 3D NAND's vertically tiered die

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