

Advancing QLC NAND Flash: Innovations and Challenges

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Agenda

- Challenges in QLC applications
- Innovations: NAND character model
 - Model building
 - Concept of enterprise SSD using the model
 - EVB test project
- Summary

Challenges in QLC applications

- **NAND characters** are more apparent
 - *e.g.*, Cross-temperature, data retention, *etc...*
- Need to pay more attentions to the data reliability issue
- Quality deviations between NAND package, block and layer increase
- It becomes more difficult to achieve ideal performance and QoS for enterprise applications

More and more tricky

Q: How to read efficiently?

Why NAND character model?

Read reference voltage (RV)

- Finer granularity
- Increasing the number of sensing
- Highly deviated

➤ KEY: acquire more accurate RV

- a model that can **PREDICT** RV
- the model can be adaptive to NAND conditions and time

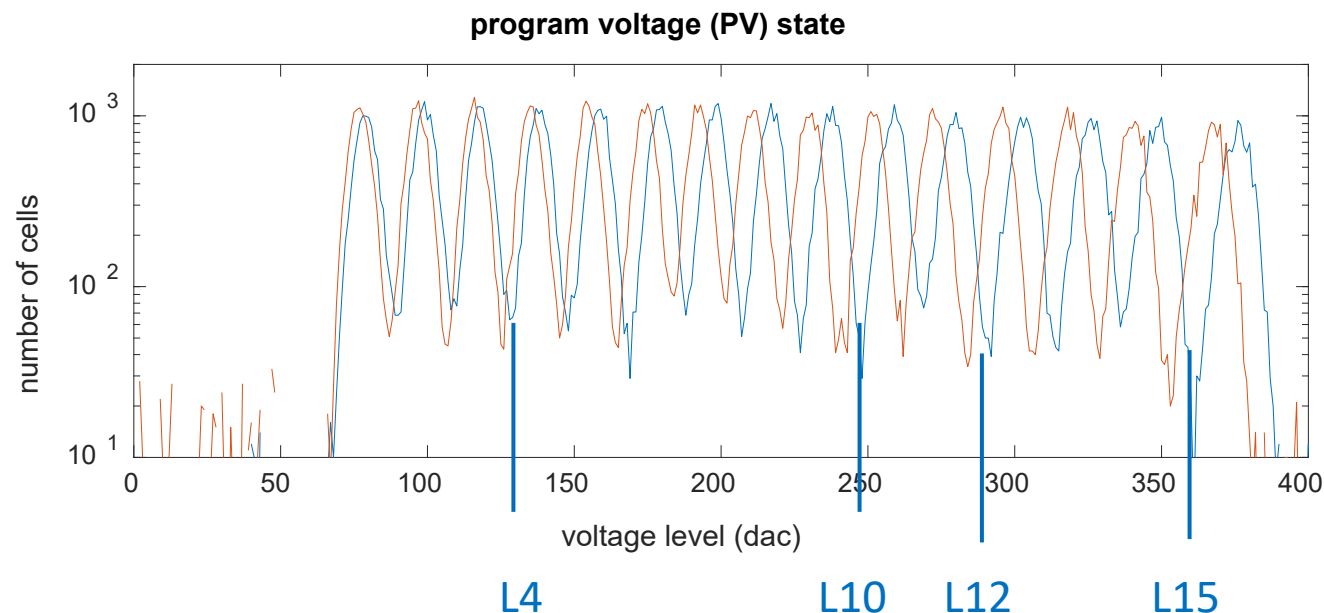
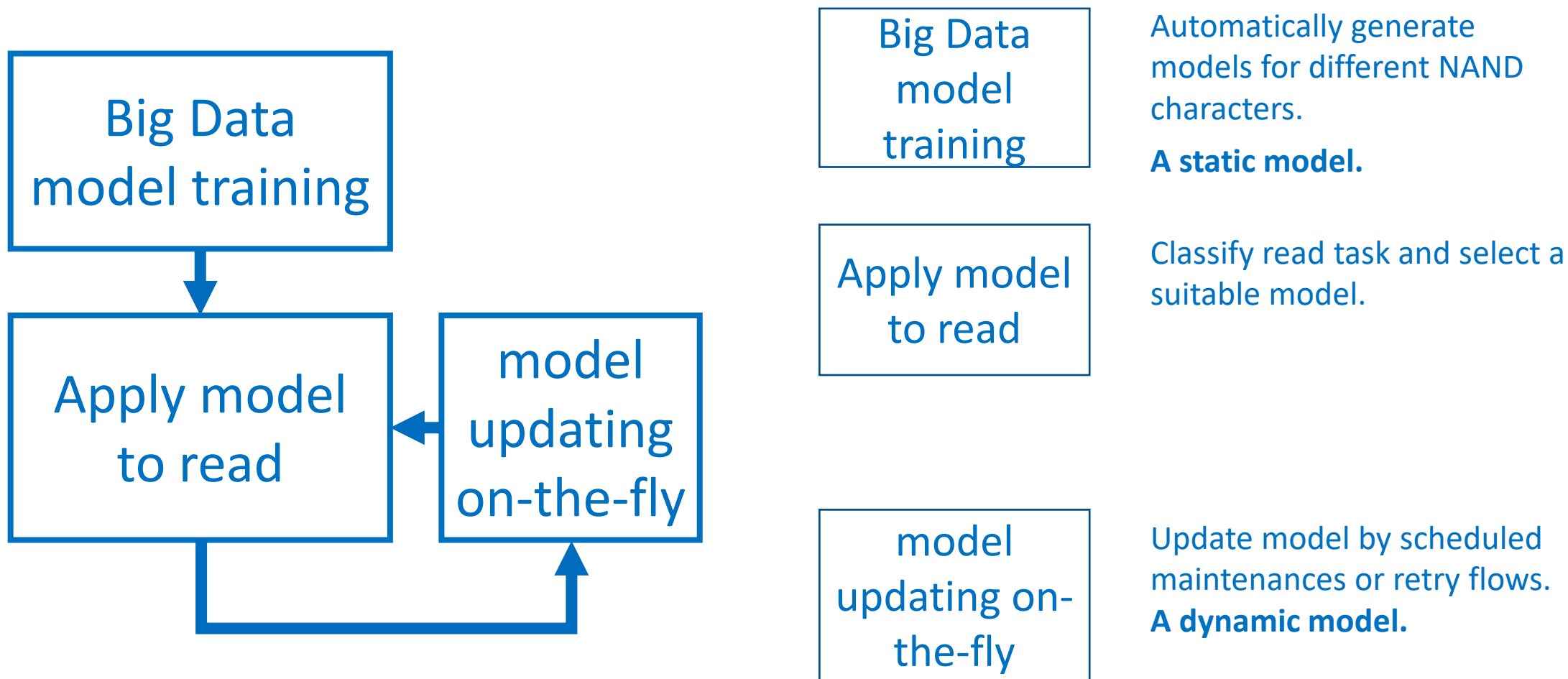
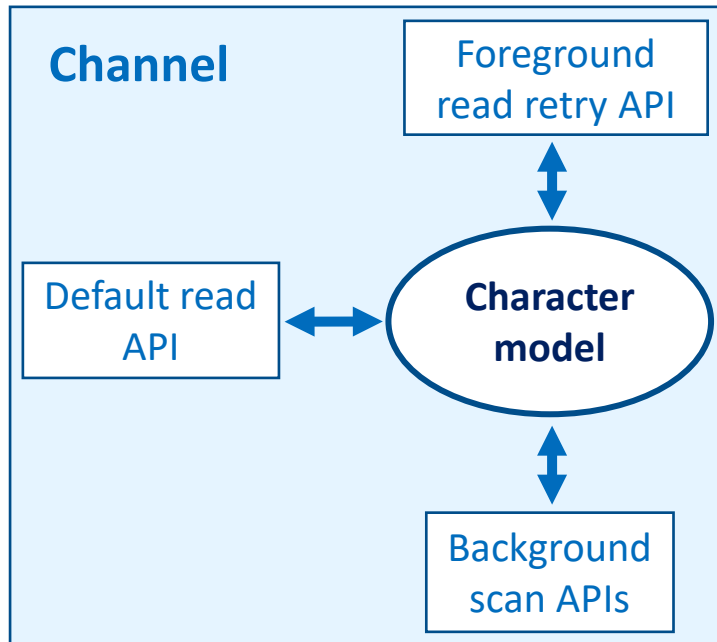


figure: 4 RVs for TP for QLC

Flow of acquiring a NAND character model



Application: Concept of enterprise SSD using the model



*For an enterprise application, a channel is an independent framework.

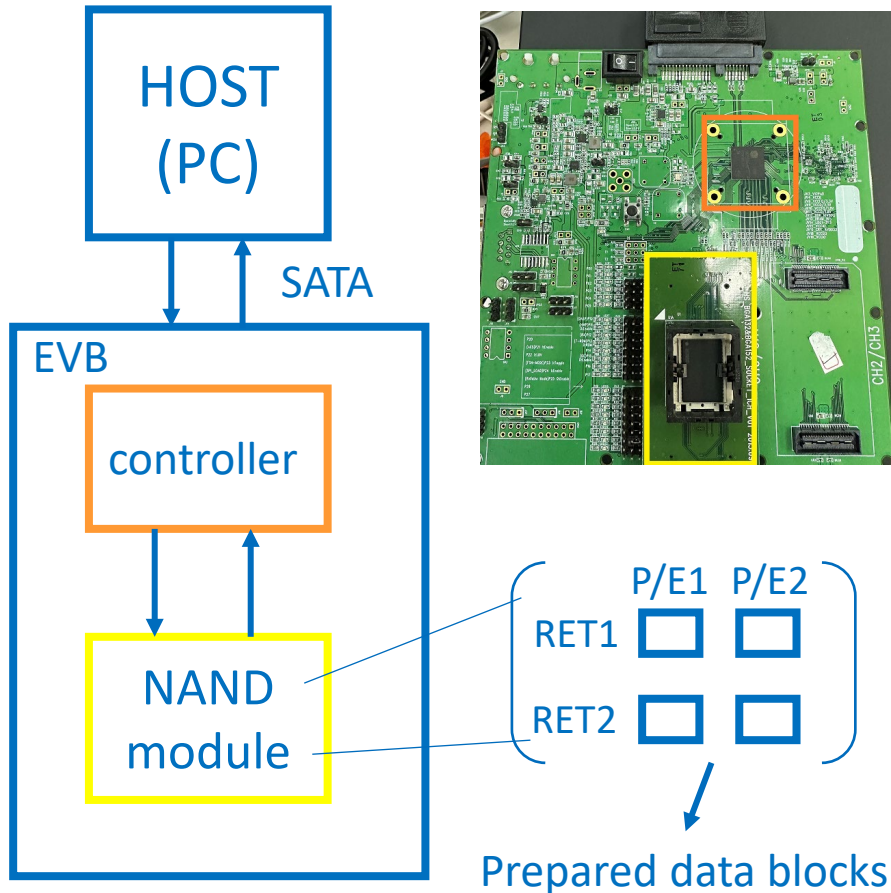
➤ Channel

- NAND character model
- Default Read API
- Foreground read retry API
- Background scan APIs

➤ Generate models via on-the-fly

- Improving the efficiency of identifying unreliable blocks
- Reducing the retry rate
- Speeding up the retry process
- Adjusting to deviation of manufacturing

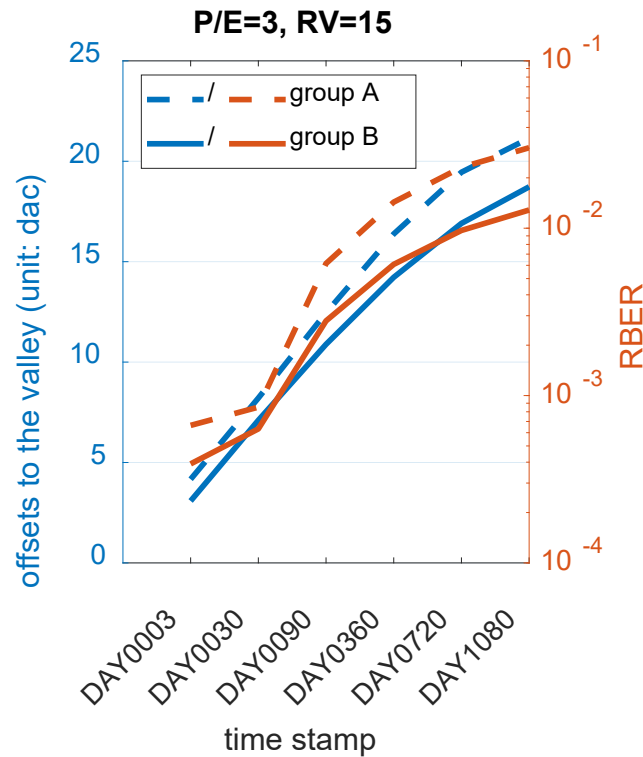
EVB test project



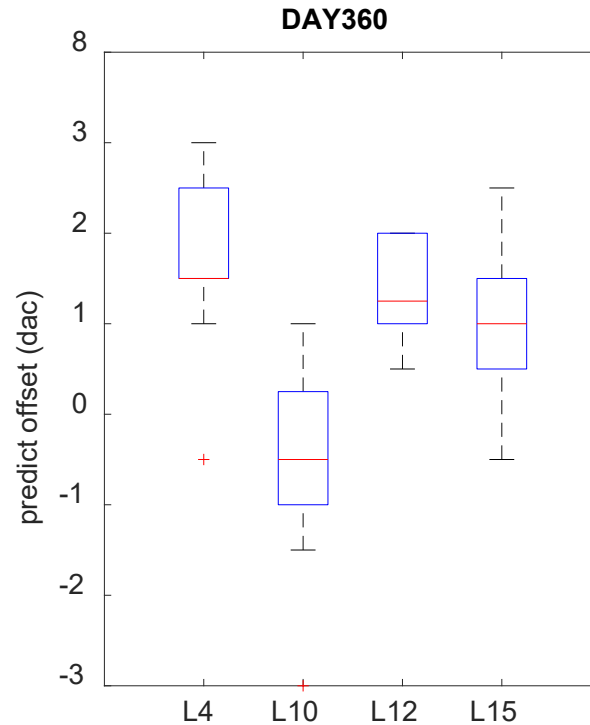
1. Collect data, e.g., cell distributions for prepared blocks.
2. Training a model that takes multiple factors and generates the corresponding RV values
 - $(RVs) = f_{\text{model}}(\text{page type, PE cout, RET, ...})$.
3. Updating the model while **retrying**.
4. Testing this model by reading another NAND module.
5. The accuracy is measured by the HOST in terms of the raw error bit number or predicted RV differences
 - Model accuracy
 - Static/dynamic model

RET: data retention time

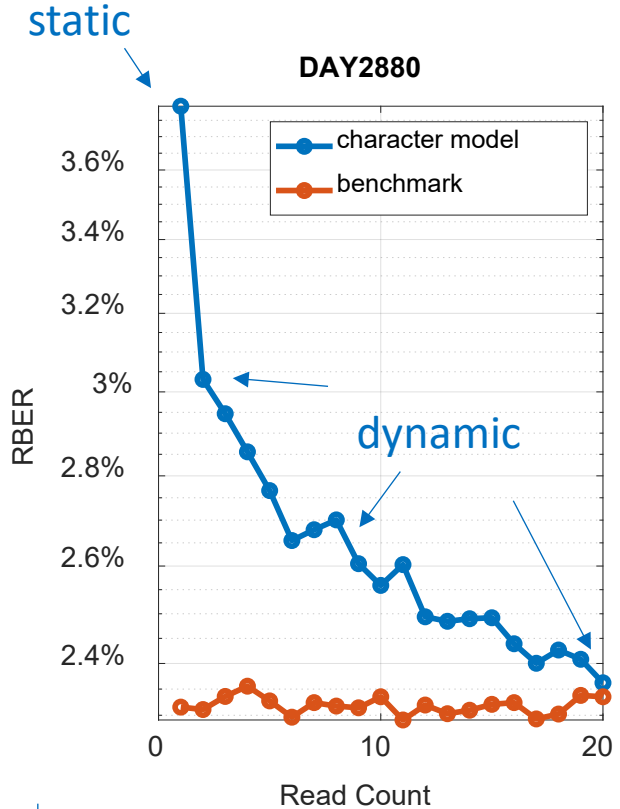
EVB test results



NAND character model
x axis as input
y axis as output



Accuracy of the model
for TPs.



Converge speed.

Summary

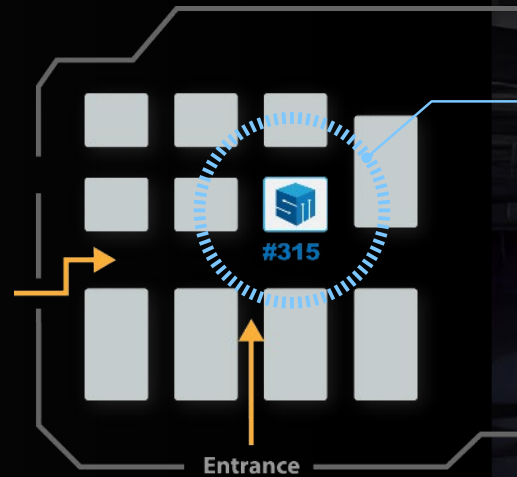
- The changes from TLC to QLC or even PLC may not be trivial; both reliability and performance are needed to address.
- We proposed a solution using the idea of model prediction. This solution naturally fits to enterprise applications.
- The model prediction can further expand to other NAND characters, such as predicting the wear levels, lifetime, maintenance periods, etc...



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From a backend FW engineer

Degrading in performance (NAND-wise)

- Read busy time↑
- Multi-pass program, program busy time↑
- Endurance and reliability ↓

Increasing in storage capacity (system-wise)

- Higher throughput interface (e.g., PCIE-g5, DDR5)
- More power consumption / more heat
- More spaces for logical to physical mapping table (FTL)

To sum up

- increasing in capacity and degrading in quality
- sophisticated algorithms for data management and maintenance