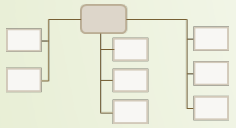
Secure Software Update in Modern Software Architecture

University of Michigan - Dearborn

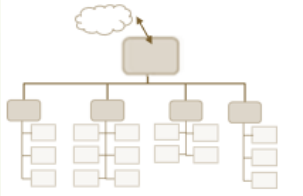
Abir Bazzi, Dr Di Ma, Dr Adnan Shaout

Trends in Automotive E/E architecture

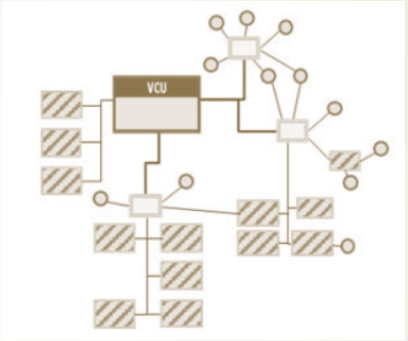
Distributed E/E Architecture

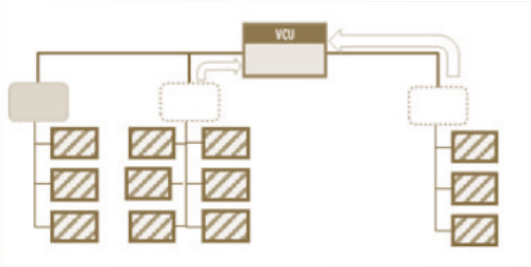


Domain E/E Architecture



Centralized E/E Architecture





Domain Controllers

ECU

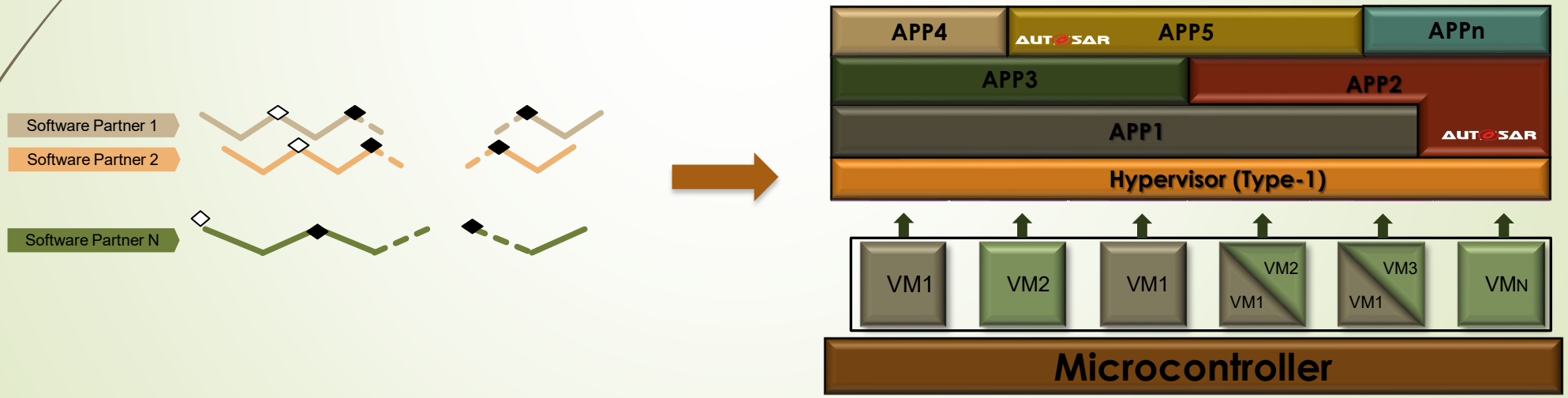
Today → Tomorrow → Future

Automotive Software Architecture

- Most OEMs follow AUTOSAR Software standardized modular architecture:
  - AUTOSAR is a worldwide development partnership of different manufacturers and companies within the automotive industry.
  - The Classic Platform is AUTOSAR's solution for embedded systems with hard real-time and safety constraints.
  - The AUTOSAR Adaptive Platform is AUTOSAR's solution for high-performance computing ECUs to build safety-related systems for use cases such as highly automated and autonomous driving.
- Due to automotive industry growth and development, AUTOSAR has introduced a new concept "Flexible" Classic Autosar:
  - Decompose the software into independent software clusters. This enables separation of Functions, shorter development cycles as well as independent development between software owners.
  - Every changed software cluster is programmed independently from the others and the whole ECU is executable and functional with an intended combination of changed and unchanged clusters.
- Virtualization is another innovation technology for hard real-time automotive applications.
  - Multiple Virtual machines (VM) execute together over a shared hardware platform and in isolation from each other.

Modular Software Architecture

- Empowering of different software vendors contributing to same ECU
  - Enabling independent SW build units.
  - Enabling independent updating of Software parts and their execution.
  - Enabling independent set of library functions: Security, Safety, communication, memory….
  - Enabling Clustering of QM and safety related Software.
  - Enabling Clustering of SWCs and BSW modules.

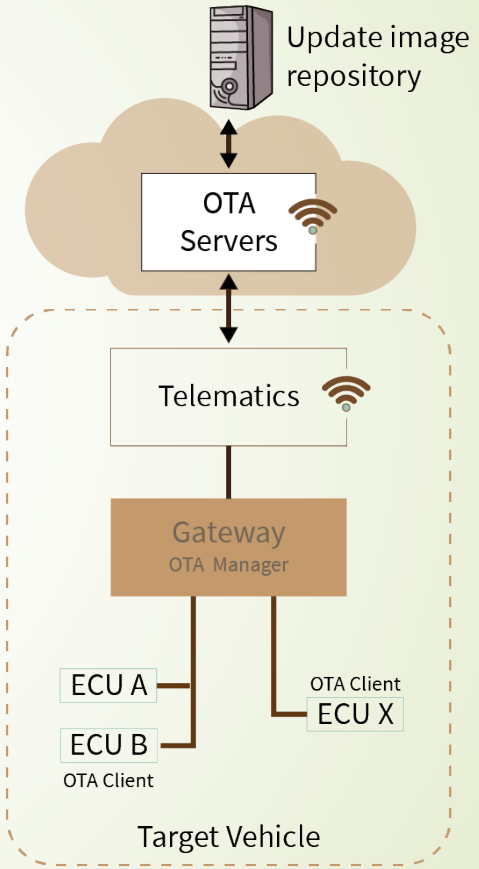


Software Update

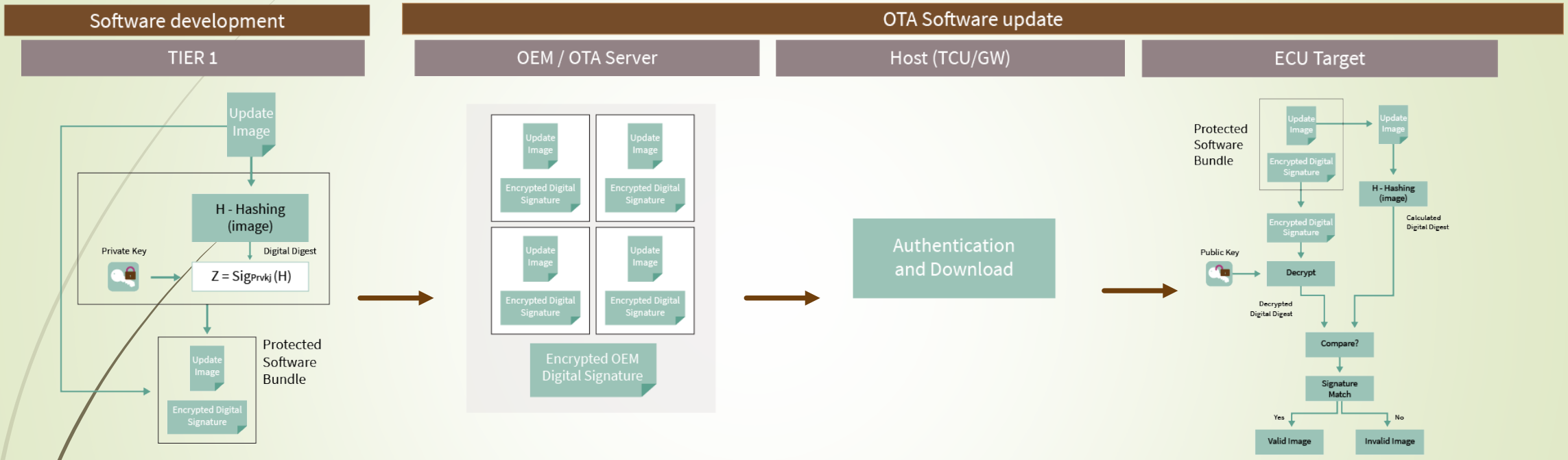
- Two types of Software Update:
  - Local update: traditional software update technique, where cars are brought to the service center and a car mechanic updates the software using dedicated tools through OBD connection.
  - Remote (Over-the-air) Update: Software is sent to the vehicle through wireless communication, while the vehicle is running.
- The main drawback of local update method is time, resource consuming and can only be done at dealership:
  - Resulting in high cost and customer dissatisfaction.
  - SW update delay can lead to Security vulnerability.
- OEM Benefits for Over-the-air (OTA) updates:
  - Fast and Cost effective – no recall required.
  - Ability to patch critical bugs/security vulnerabilities as early as possible.
  - Revenue generation with new features.

OTA updates: A brief explanation

- Step 1: Download while driving
  - Software download to central storage
  - Unnoticed by the user
  - Vehicle safe and operational
  - Service authentication:
    - Mutual authentication between car and OEM update server
    - Encrypted transport channel
- Step 2: Update from internal storage
  - Verification of the downloaded software
    - SW-IP protection (e.g. Encryption / Decryption)
    - Integrity Check (e.g. Hash)
  - Update to the new Software image
  - Confirmation to Backend



Secure software OTA update process



Signature relies on a **private** key associated with the public key used by the end ECU

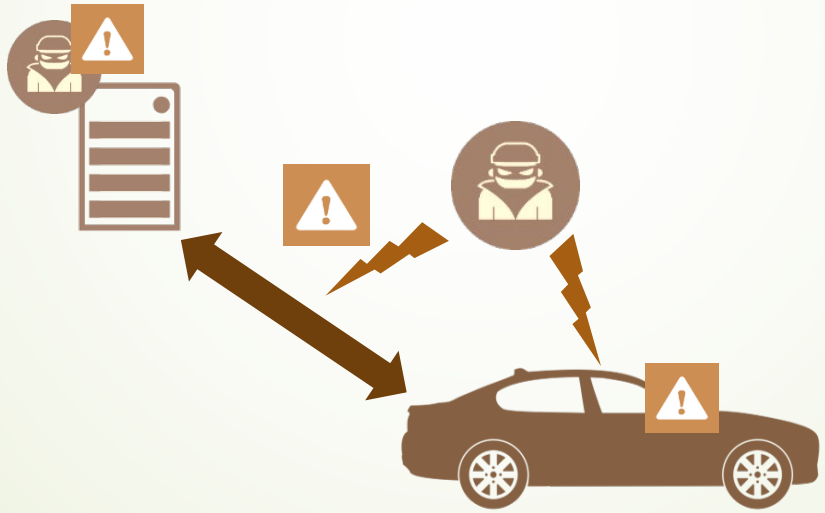
Signature relies on a private key issued by the update root certification authority

Signature verified using public key stored in TCU

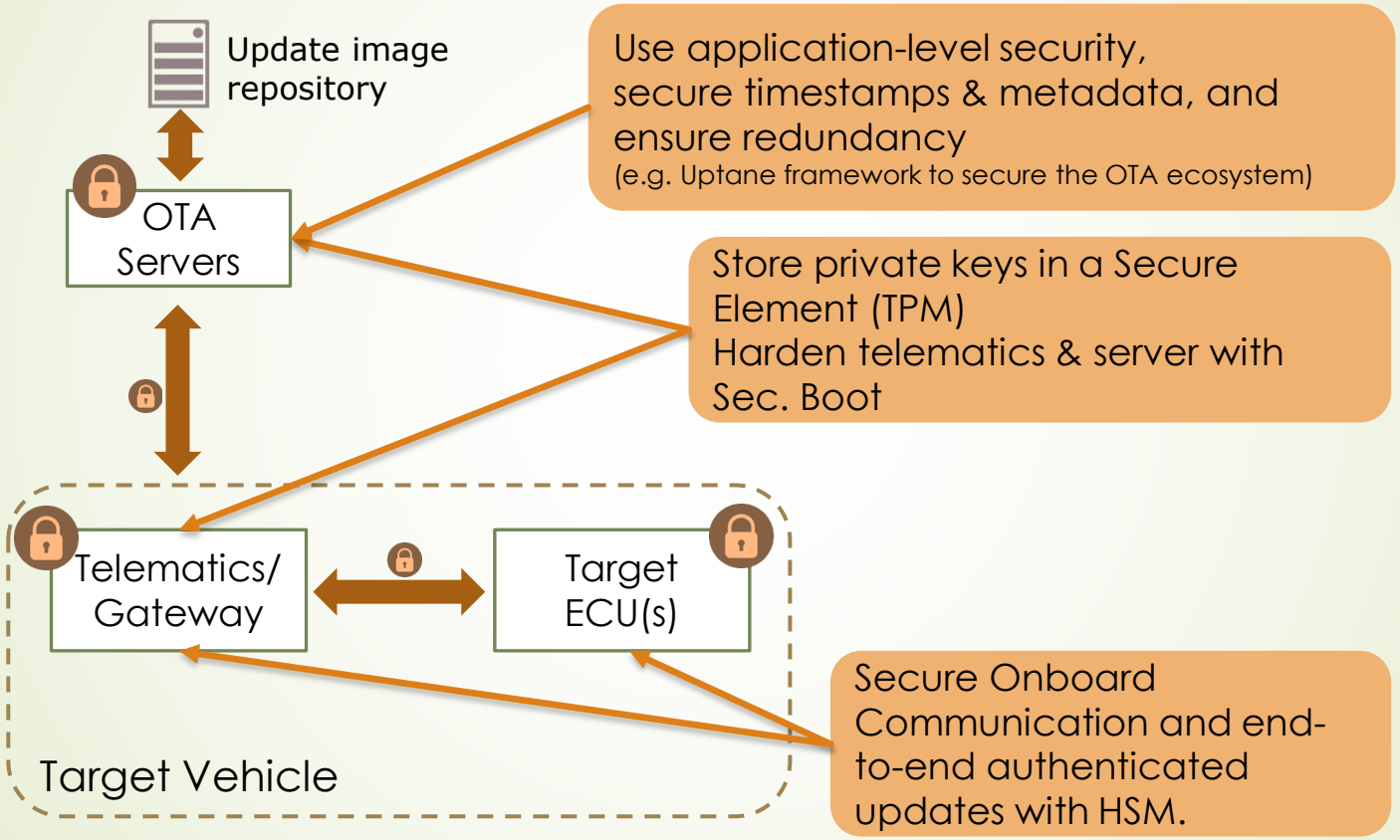
Signature relies on a **public** key associated with the private key used when bulding the image

Security Threats are Safety Threats

- Connections are typically active all the time and thus OTA interfaces are potentially accessible for hackers.
- SW OTA services provide doors for attacks which might endanger the operation of vehicles.
- Already the potential to attack vehicles is threatening Tier1s and OEMs.

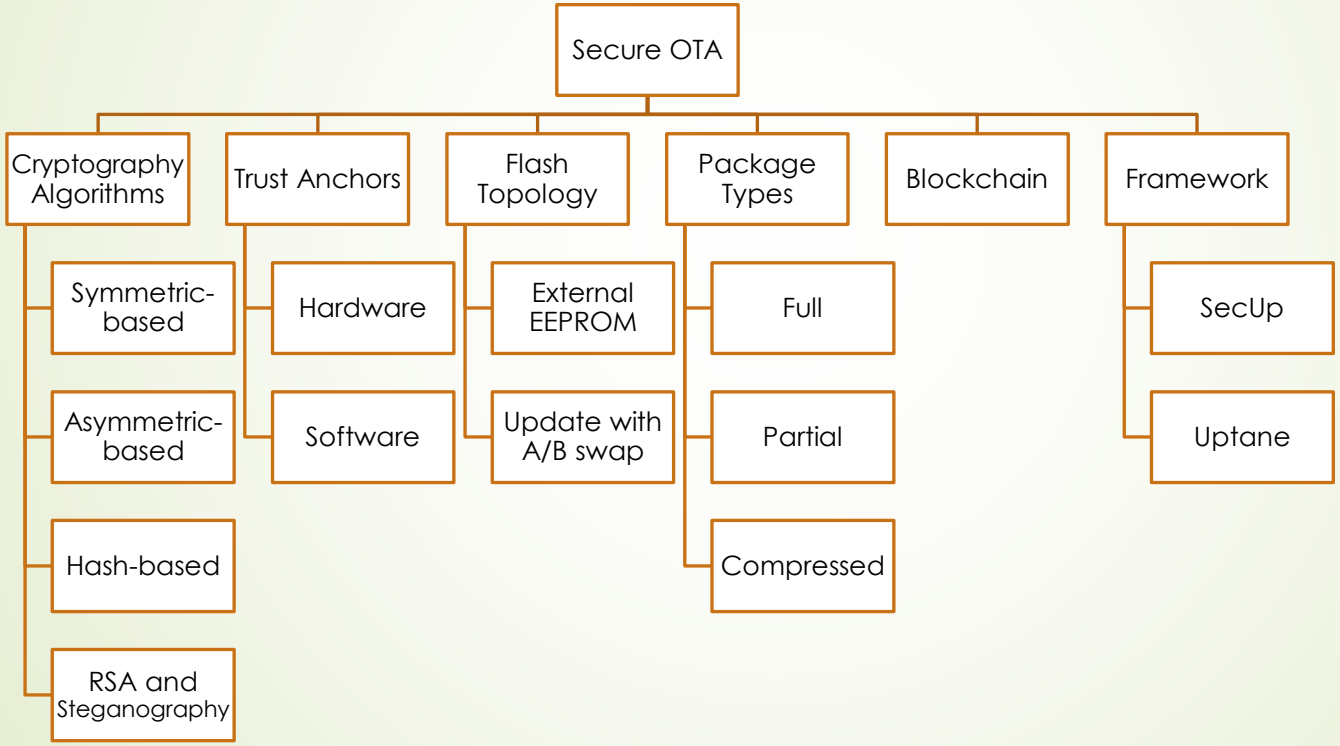


Existing Security mechanisms



Existing secure SOTA solutions

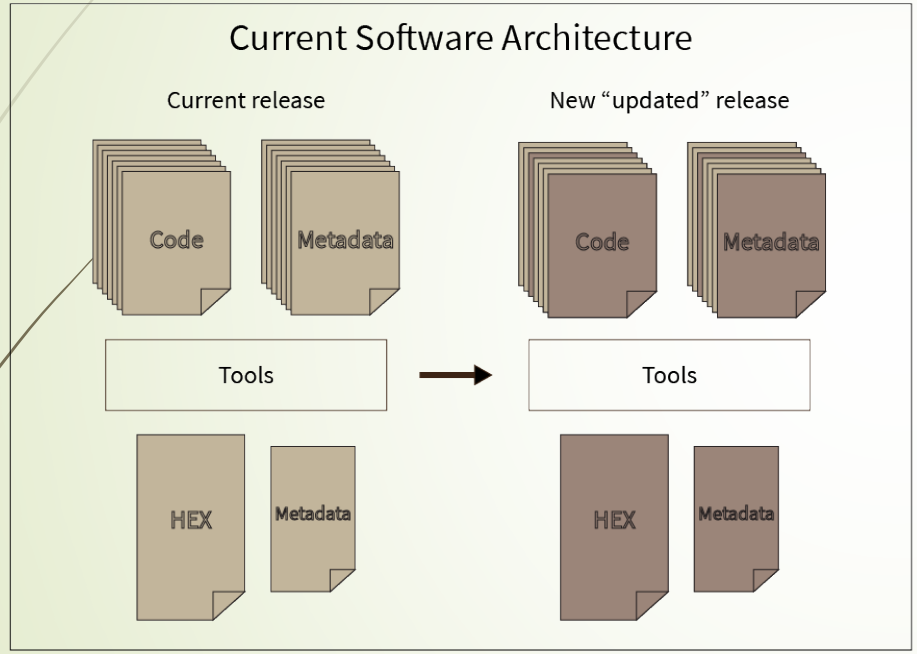
- Categorized based on the security mechanisms used by researchers.
- Follow the same described process.

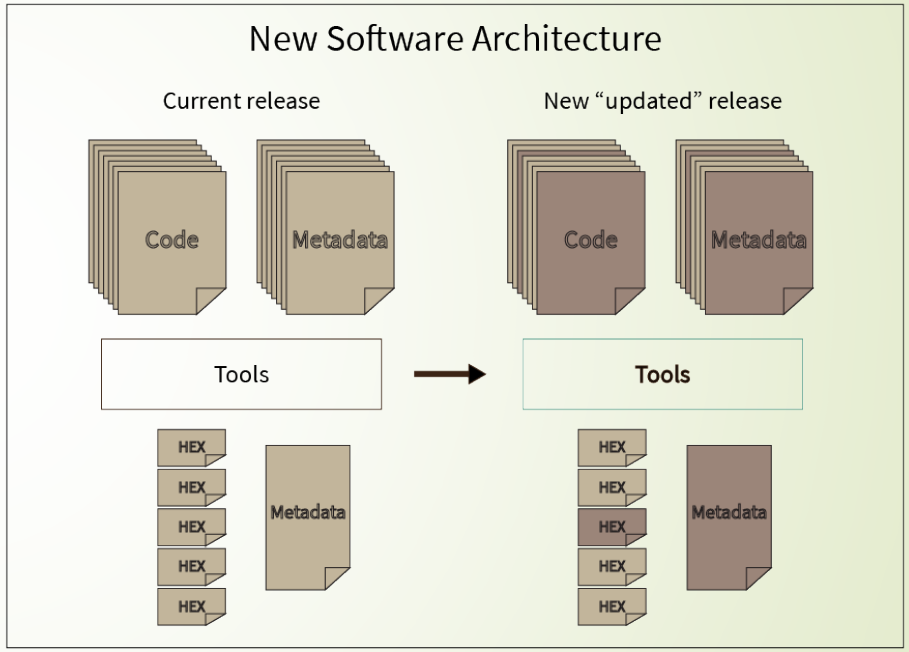


Secure Key deployment

- Create asymmetric key pair by OEM for each ECU:
  - Public/Private key using Asymmetric Algorithm (e.g. RSA/ECC).
  - Store public and private keys in Secure area / Protected Flash.
  - Public Key should be send to the ECU: mainly at the end of production line or later on the field using PKI system.
- Setup phase at the ECU side:
  - ECU receives public key.
  - Application imports the public key in cryptographic library.
  - Store public key in Protected Flash, mainly in TPM/HSM.

Software Release Process





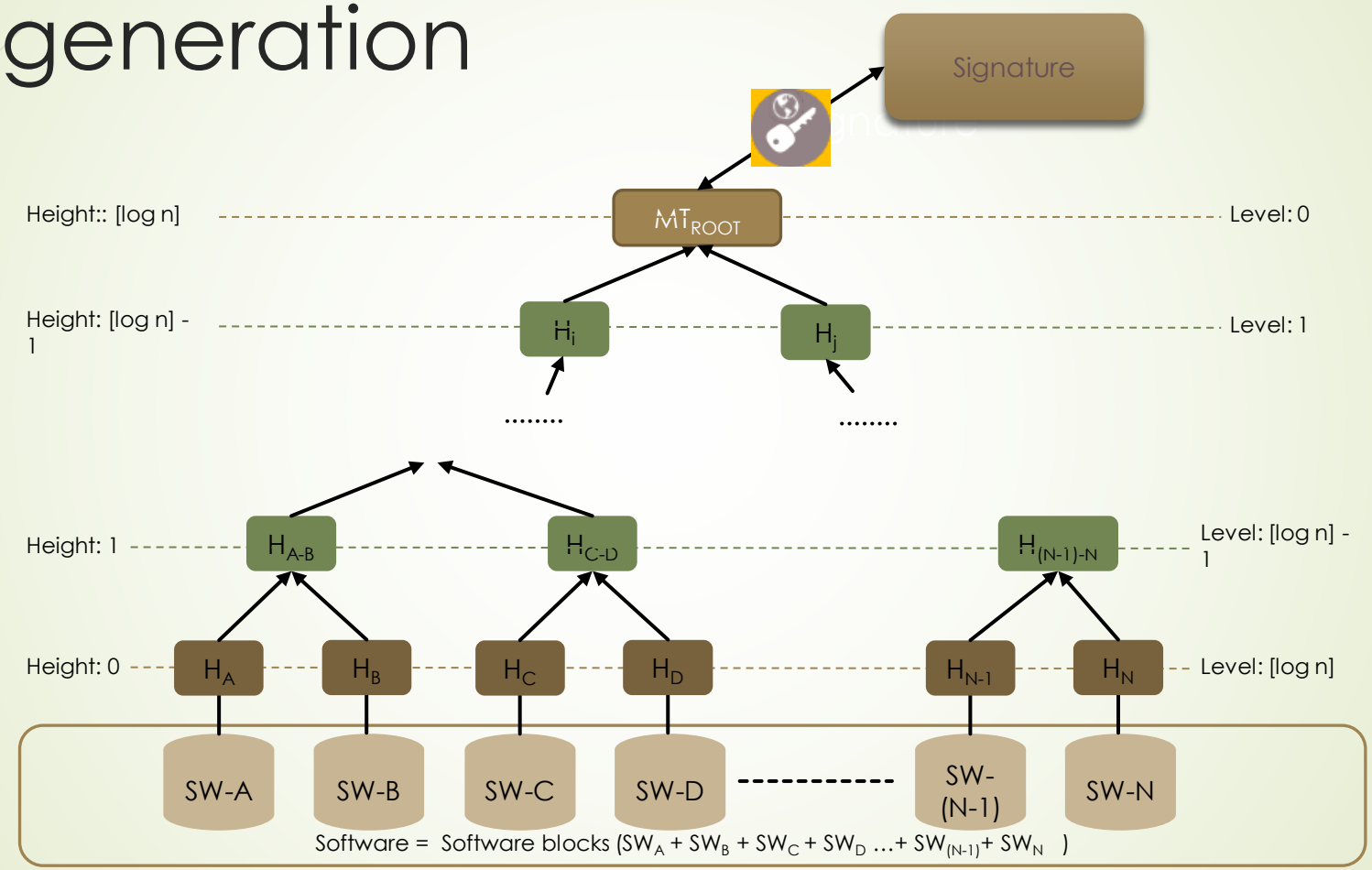
Challenges of OTA approaches

- Using existing SOTA mechanisms, the complete application software image is updated together per ECU .
- Adaptive Autosar integrates the software update concept within the standard by standardizing the process and responsibility. However, Classic Autosar doesn't have the same capabilities.
- Each ECU will need a unique set of keys per each software cluster shared between each developer and ECU Target.
- Increase complexity in key management, deployment, and storage.
- Limitations with current microcontrollers and Flash technologies due to performance and memory granularity (e.g. limited number of erase/write cycles).

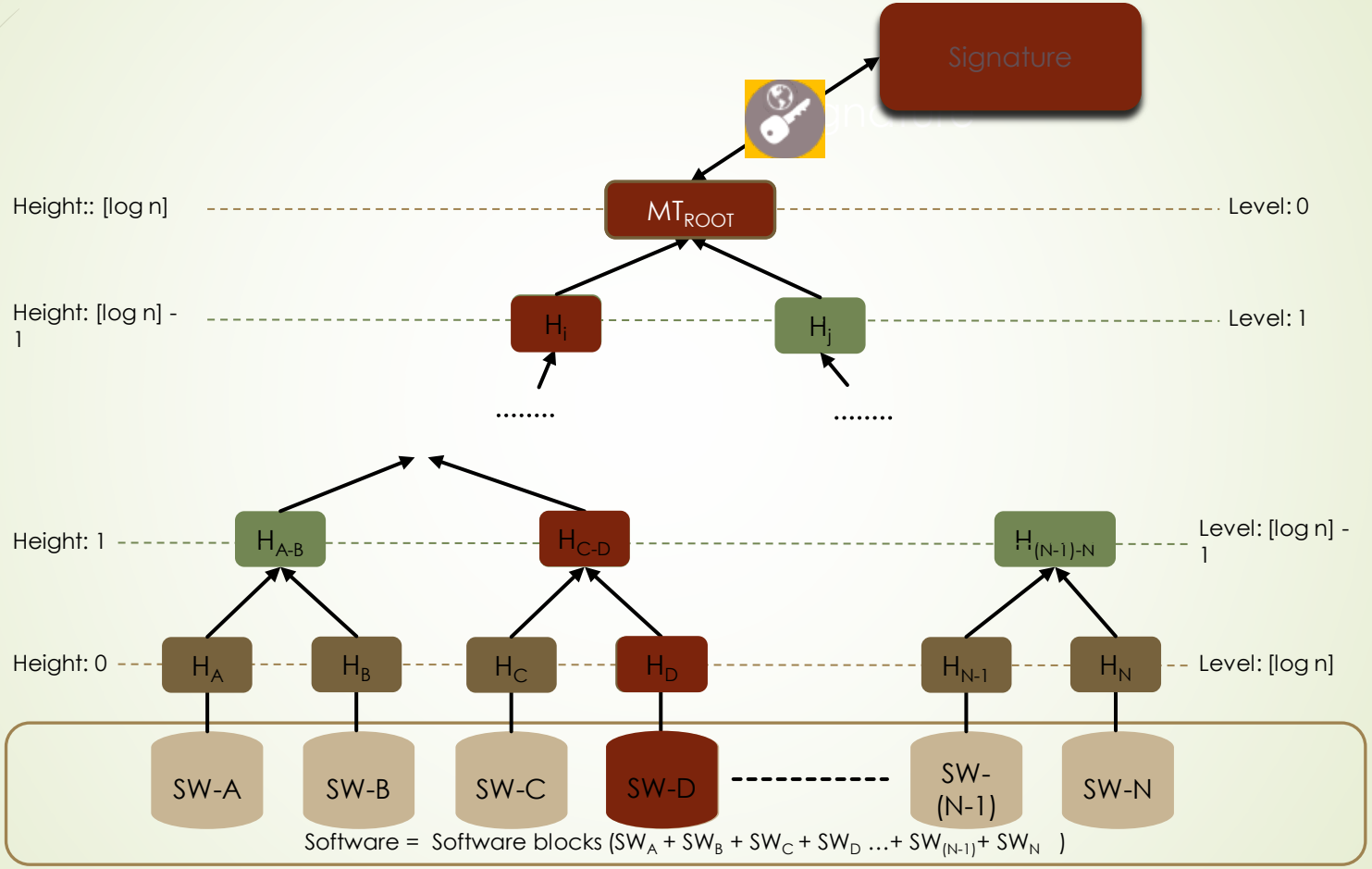
SOTA Solution: New proposal

- Extend existing solution with features oriented for distributed systems
  - Uptane framework, Autosar platforms…
- Address dependencies and conflicts among the software entities.
- Logical implicit verification.
- Efficient Key deployment and management.
- Optimize code signing scheme and ECU resources.
- Generate unique signature based on Merkle-Tree concept.
- Solution flexible and applicable for various applications and security use-cases.

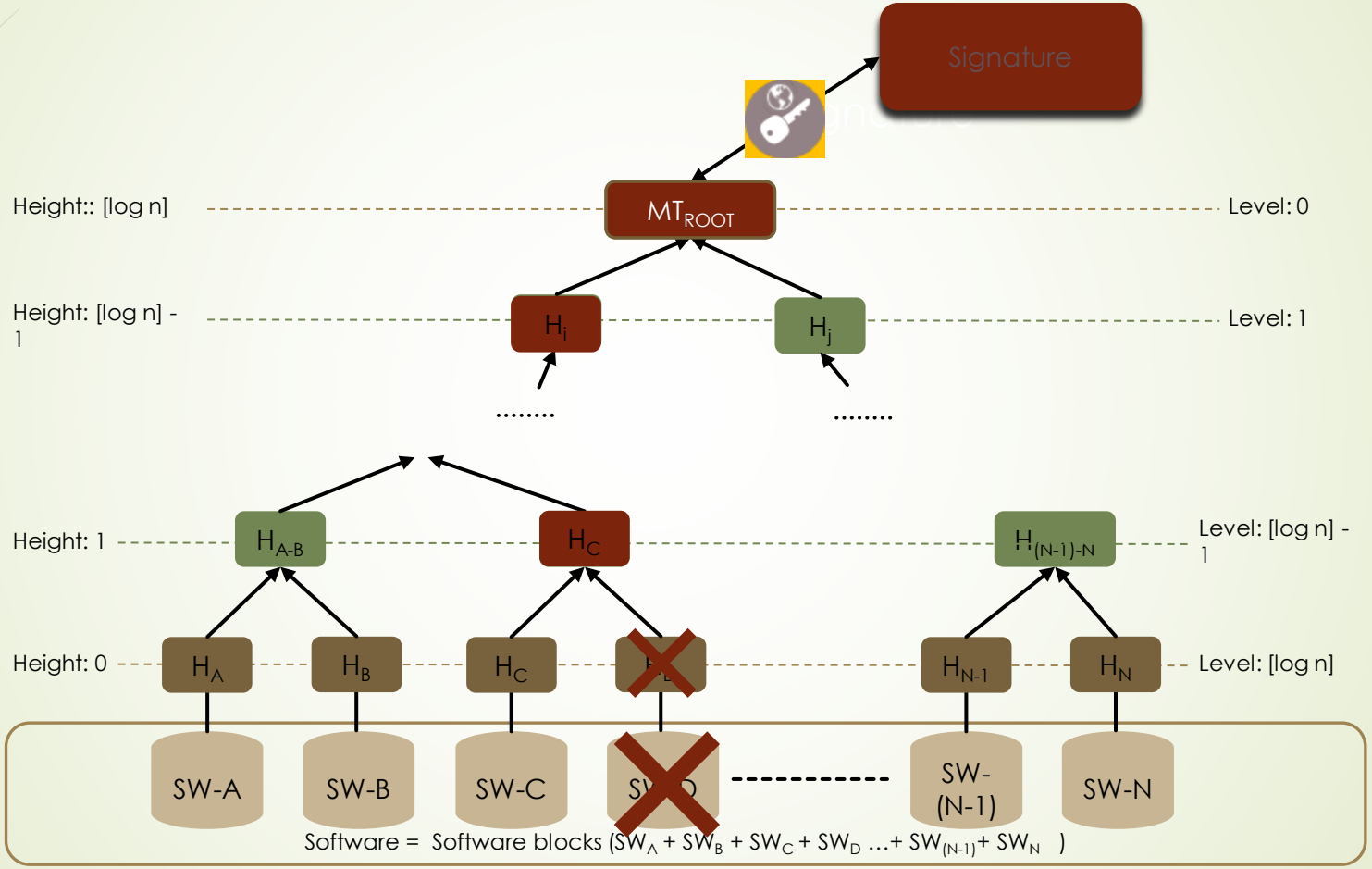
Proposed Approach for Signature generation



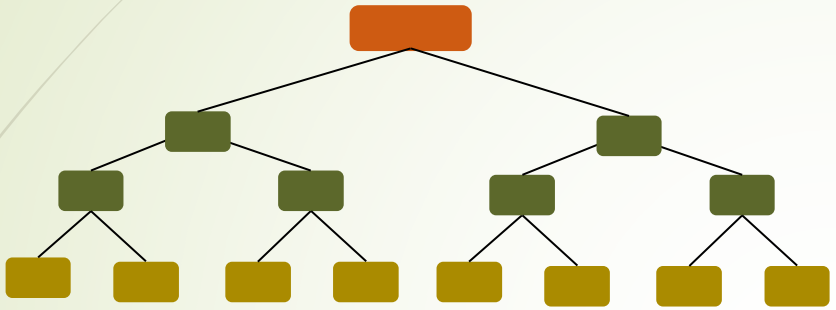
Updating Single Software entity



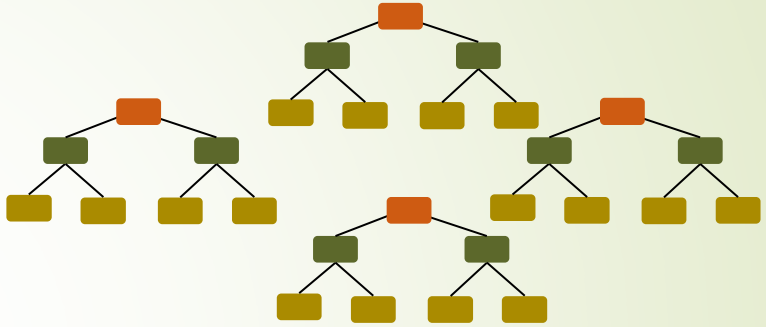
Removing Software entity



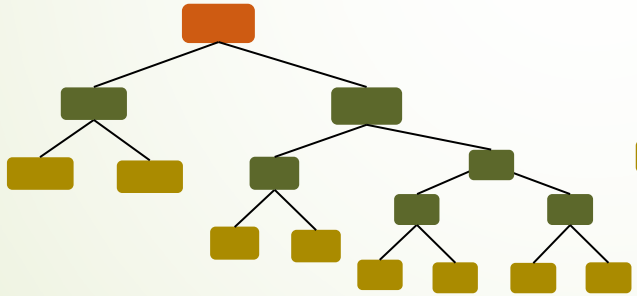
Different Merkle Tree types

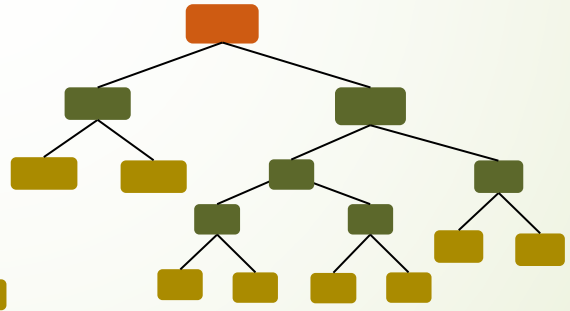


(a) Full balanced



(b) Multi-Root





(c) Skewed

Summary

- New automotive platform is seen as the "App-Store" for automotive applications for installation and update over the air.
- The authenticity and integrity of update packages need to be protected to impede the import of forged and manipulated data.
- Unique signature generation based on Merkle Tree concept:
  - Smoothly update, add, and remove software image.
  - Security and safety of the update process.
  - Authenticity and integrity validation for the software image.
  - Reduce used key materials.
  - Enable local and remote software compatibility check.
  - Recovery of software after failure during update process.
  - Suitable for future cryptographic algorithms.

Q&A

Thank you!

Any questions?