From Electronic Design Automation to Automotive Design Automation

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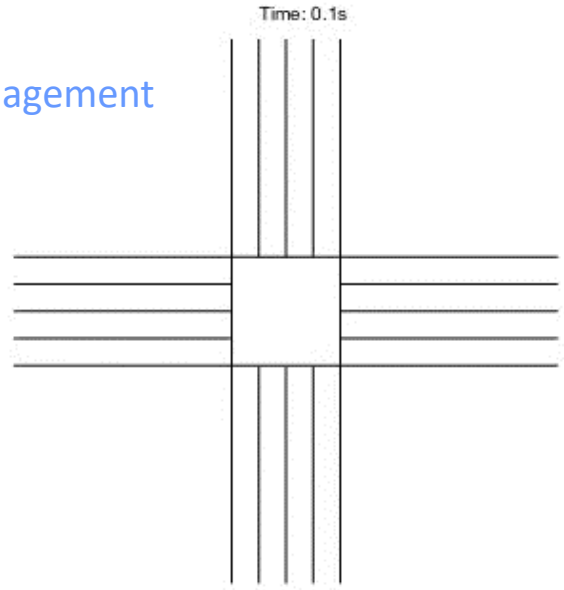
Connected and Autonomous Vehicles

- A good application may need both of "connectivity" and "autonomy"

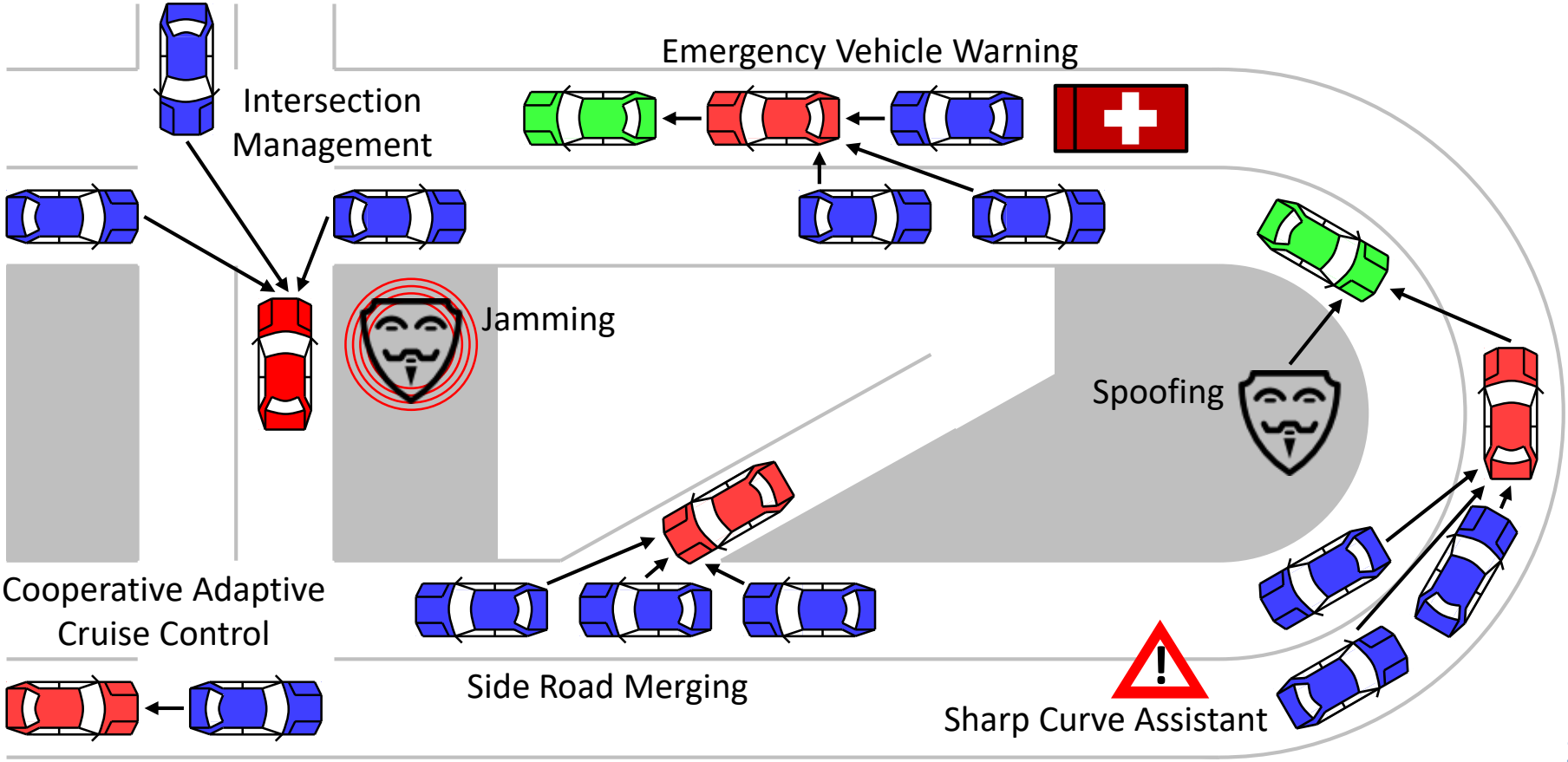
Intersection Management



  - What if the intersection management does not have connectivity?
  - What if the intersection management does not have autonomy?

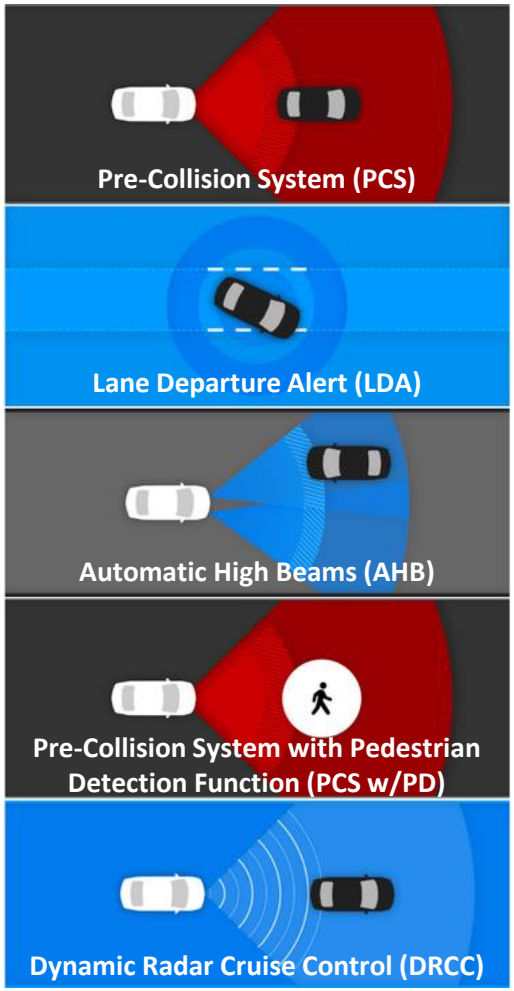
Connected Applications

- Connectivity realizes more applications, together with
  - ADAS
  - Autonomous functions



Software Design Complexity

- Various applications including Advanced Driver Assistance Systems (ADAS) and autonomous functions
- Various software programs for sensing, signal processing, control, decision making, etc.
  - Embedded software value to vehicle's total value
    - 2% → 13% from 2000 to 2010
  - Number of lines of code
    - 1 → 10+ → 100 million from 2000 → 2010 → now
- Due to the safety-critical nature, correctness and quality of software are extremely important



http://www.toyota.com/safety-sense/

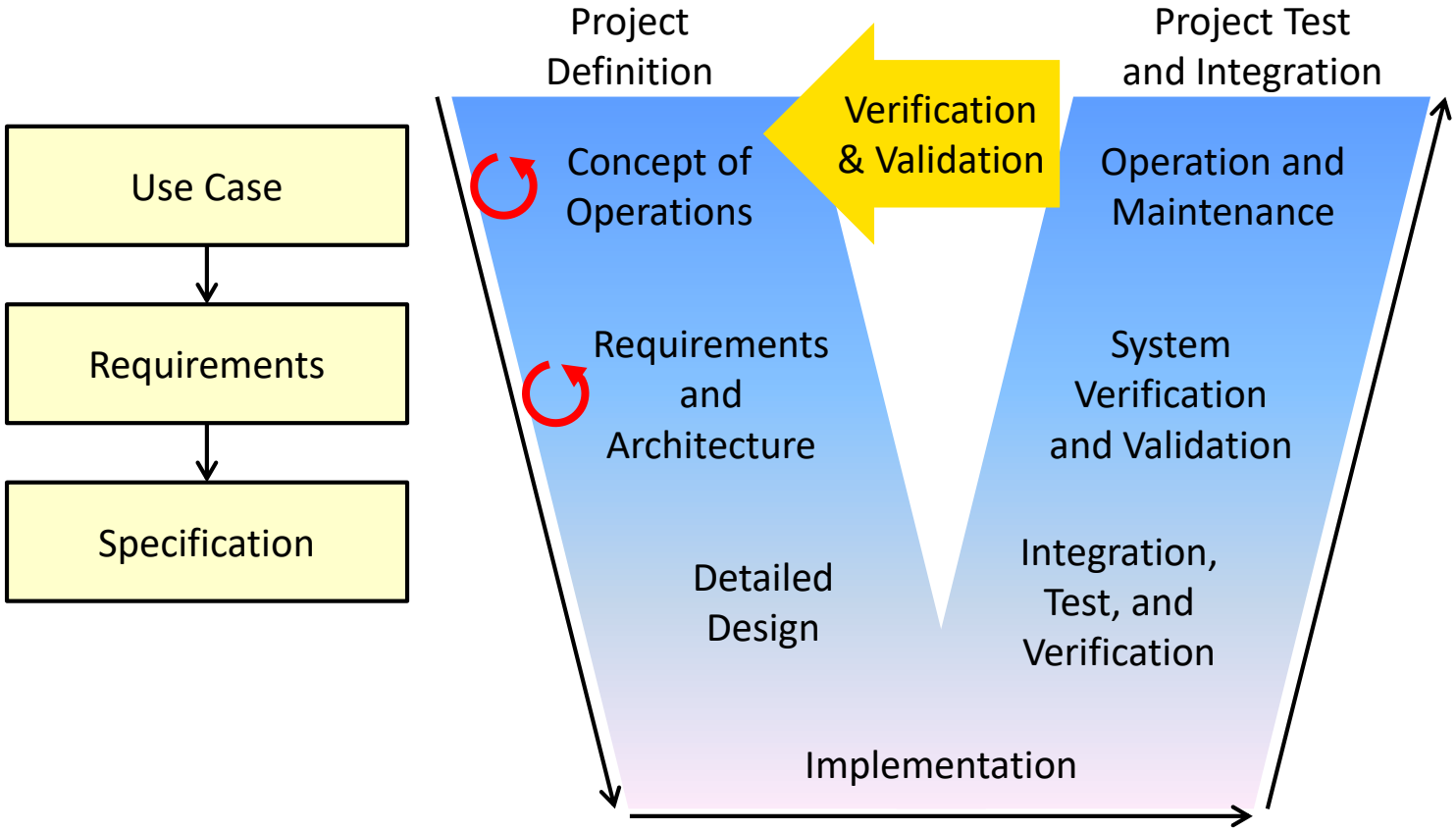
Hardware Design Complexity

- Number of Electronic Control Units (ECUs)
  - 20 → 50+ in the past decade
- Integrated architecture
  - One function can be distributed over multiple ECUs, and multiple functions can be supported by one ECU
    - More sharing and contention among software functions
    - Traditional federated architecture: each function is deployed to one ECU and provided as a black-box by its supplier
- New computational components
  - Field Programmable Gate Array (FPGA)
  - Graphical Processing Unit (GPU)
- Next-generation communication protocols
  - Ethernet-based protocols

https://en.wikipedia.org/wiki/Ethernet

"Design Automation"

- Consider different design metrics
  - Safety, reliability, robustness, performance, etc.
- Assist system designers for early design decisions



https://en.wikipedia.org/wiki/V-Model_(software_development)

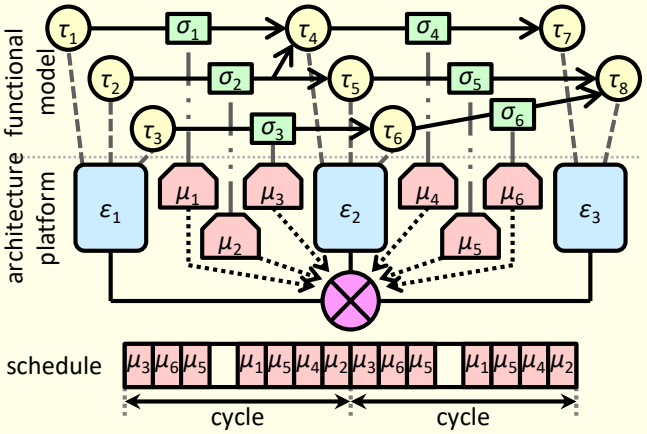
EDA vs. Automotive Design Automation

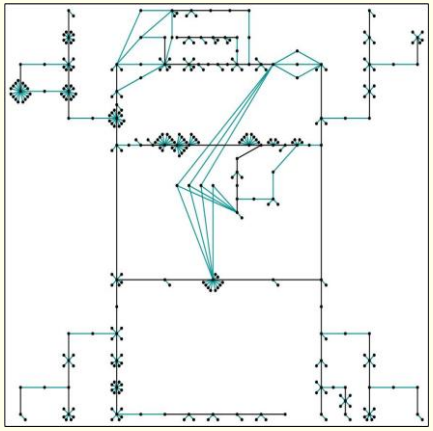
Modeling

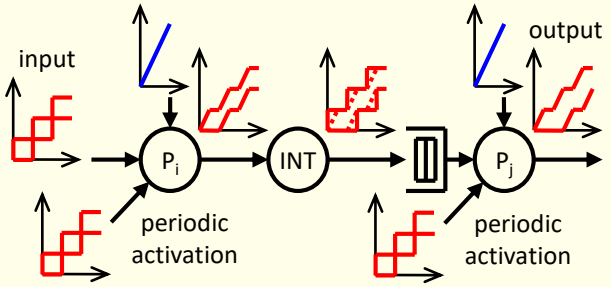
Design

Analysis

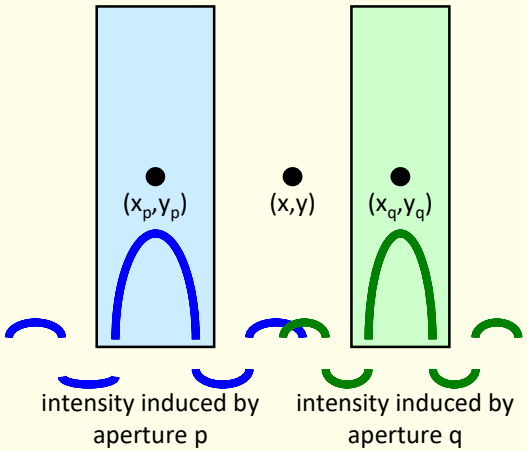
Automotive Design

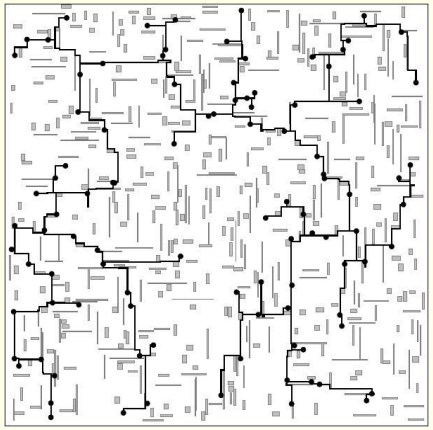


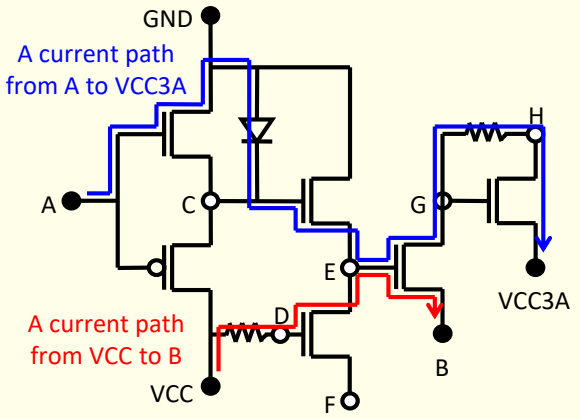




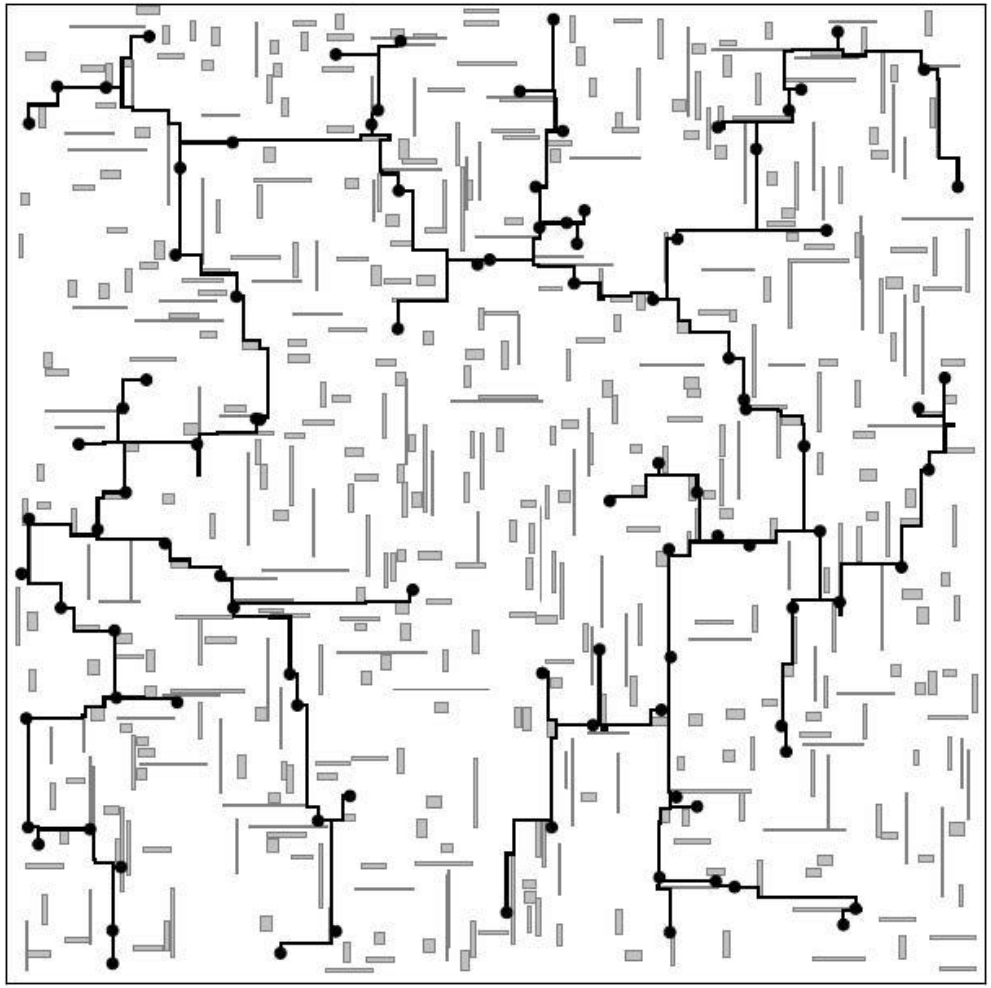
Electronic Design Automation (EDA)





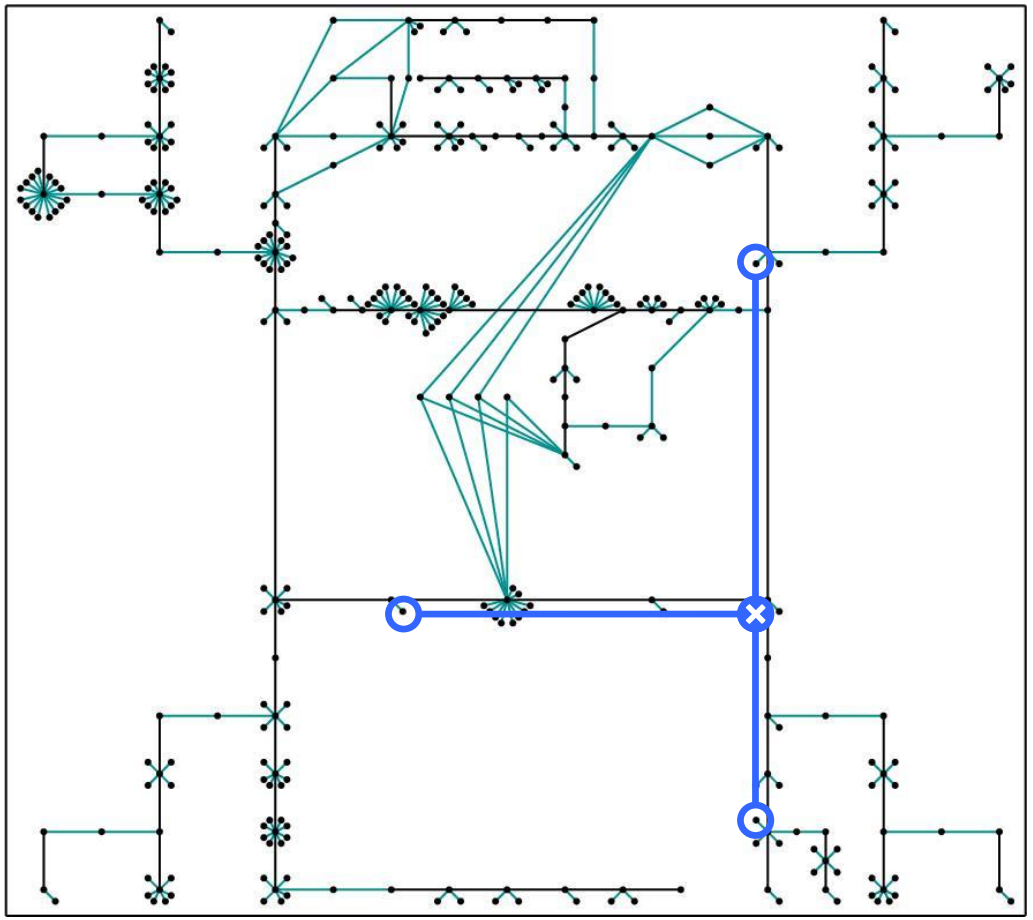


EDA: Wire Routing and Wire Sizing



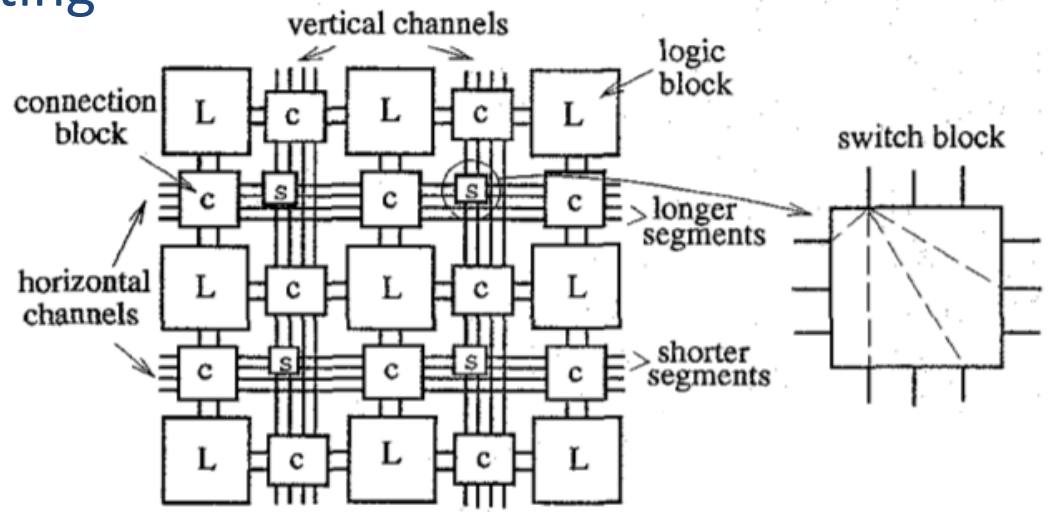
Similar Problem in Automotive Design

- The wiring weight of a system can be up to 30kg
  - The third heaviest and costliest component in an automotive system (after the chassis and the engine)
  - Netlist
    - A set of "parts" to be connected
  - Splice
    - Used for connecting more than two wires
    - Steiner vertex!
  - Where to put splices?
    - Steiner tree problem

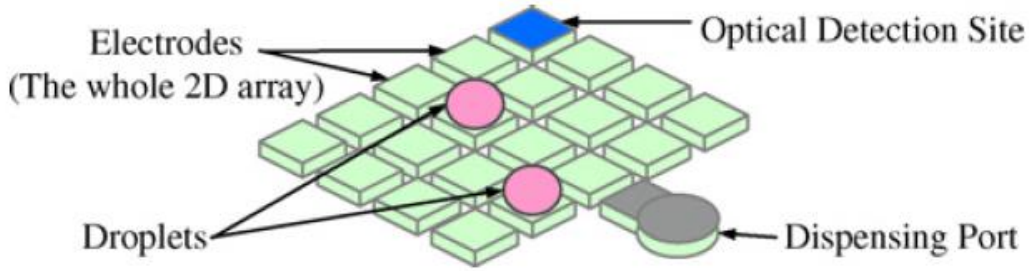


EDA: FPGA and Bio-Chip Routing

- FPGA routing



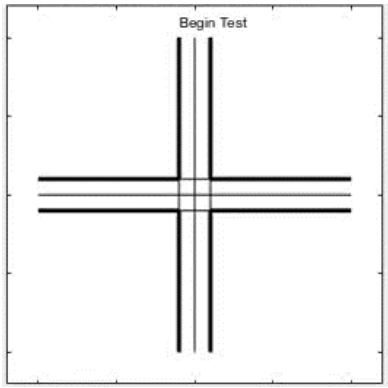
- Bio-chip routing



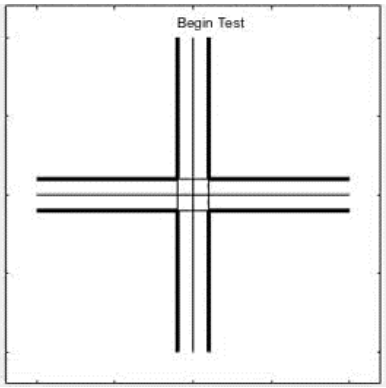
- Chang et al., "FPGA global routing based on a new congestion metric," ICCAD 1995.
- Lin and Chang, "Cross-contamination aware design methodology for pin-constrained digital microfluidic biochips," DAC 2010.

Similar Problem in Automotive Design

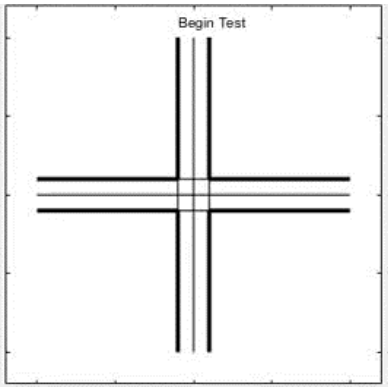
No Traffic Light + No Communication



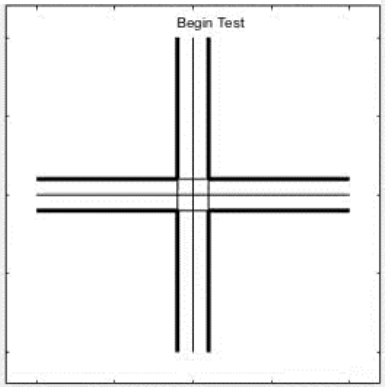
Traffic Light 5s

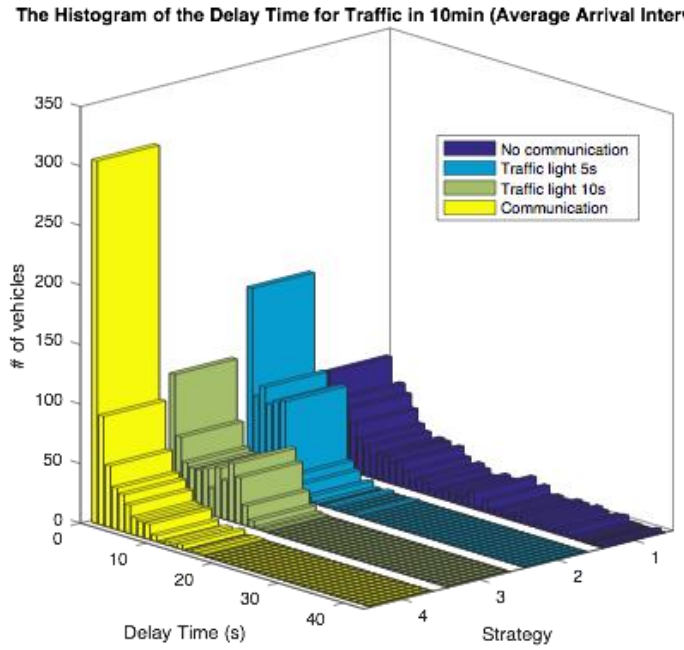


Traffic Light 10s

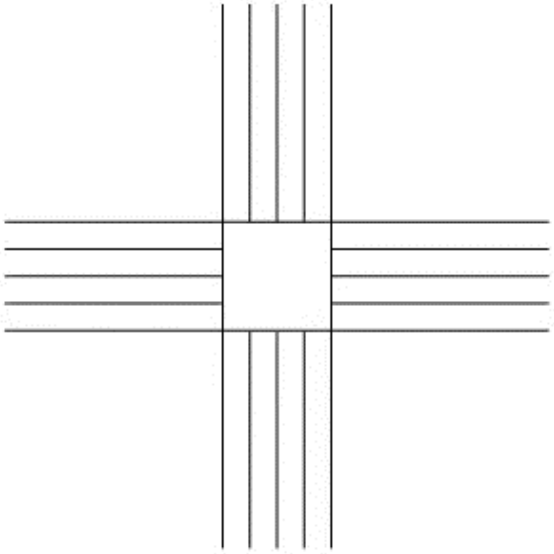


No Traffic Light + Communication





Extension to Multiple Lanes

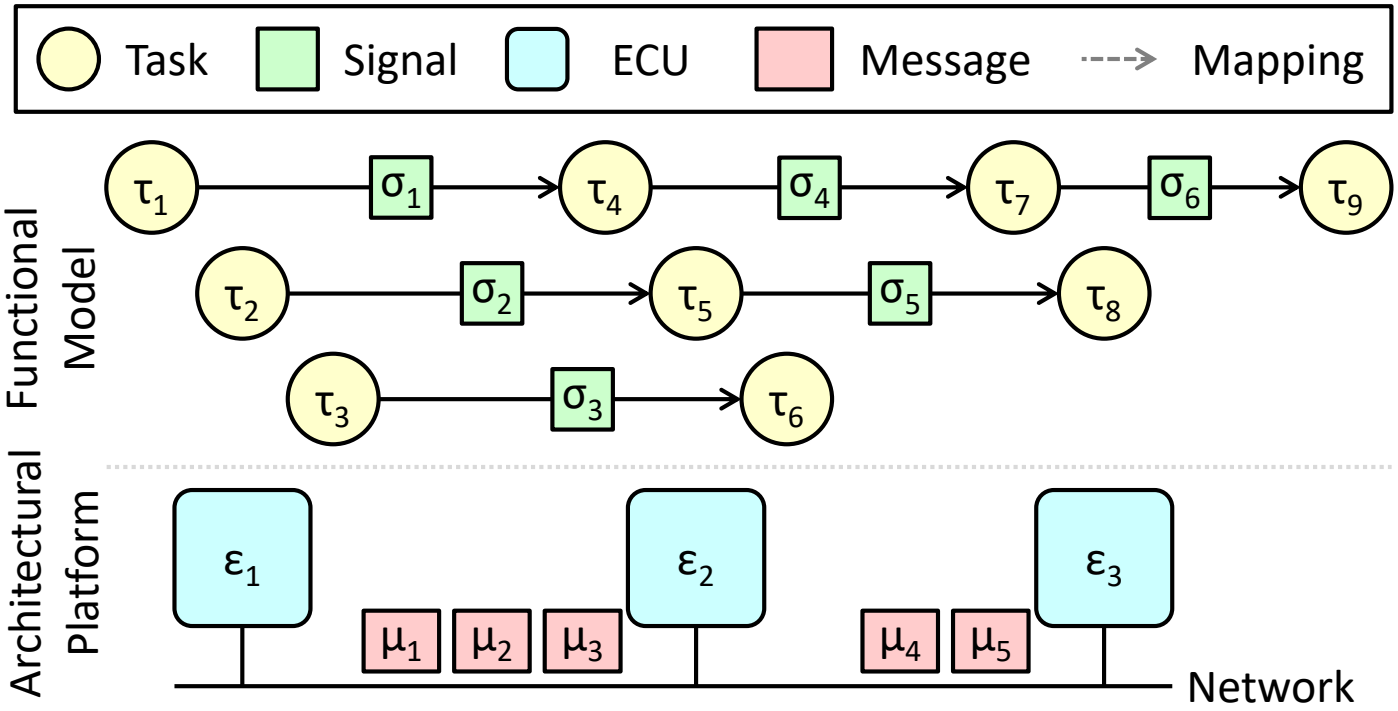


Outline

#1 **Placement**	**#2** **Verification**
#3 **Software Integrity**	**#4** **Security-Aware Design and Analysis**

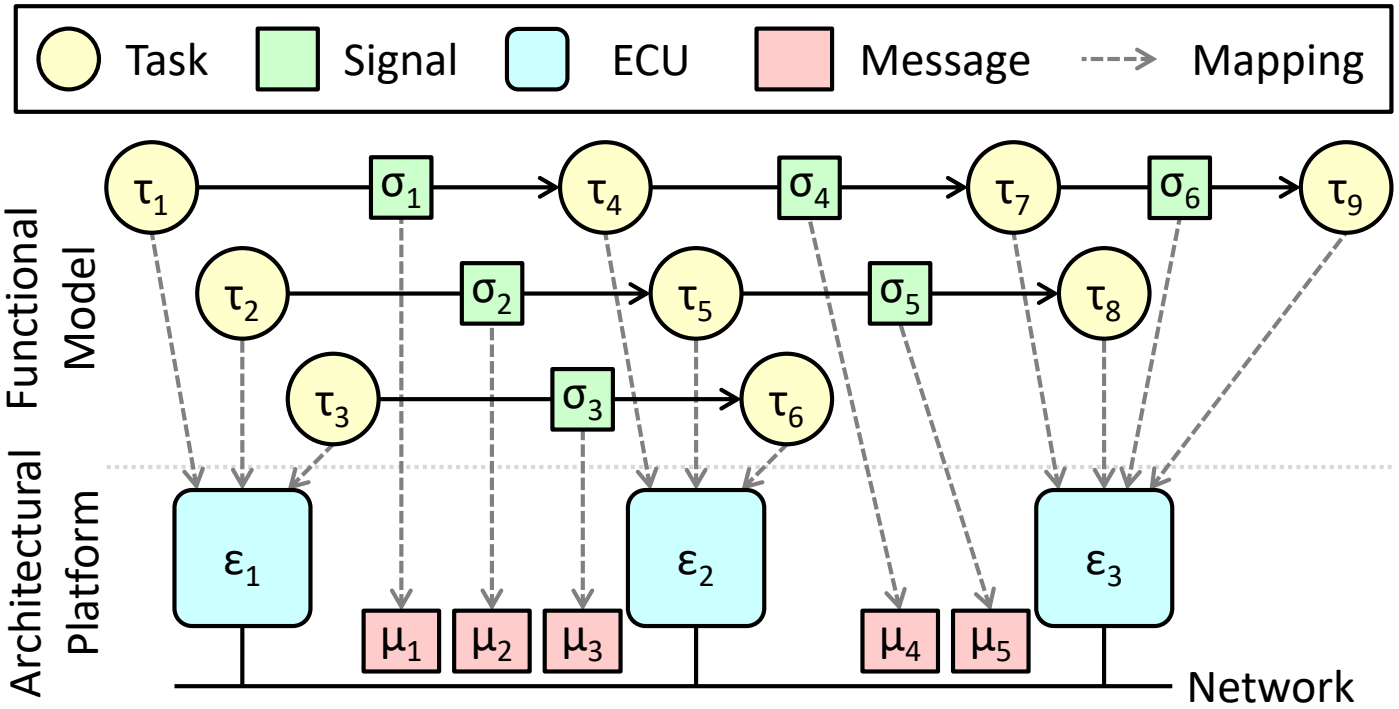
One Example Formulation

- Software (functional model): task graph
- Hardware (architectural platform): distributed Electronic Control Units (ECUs) connected by a network

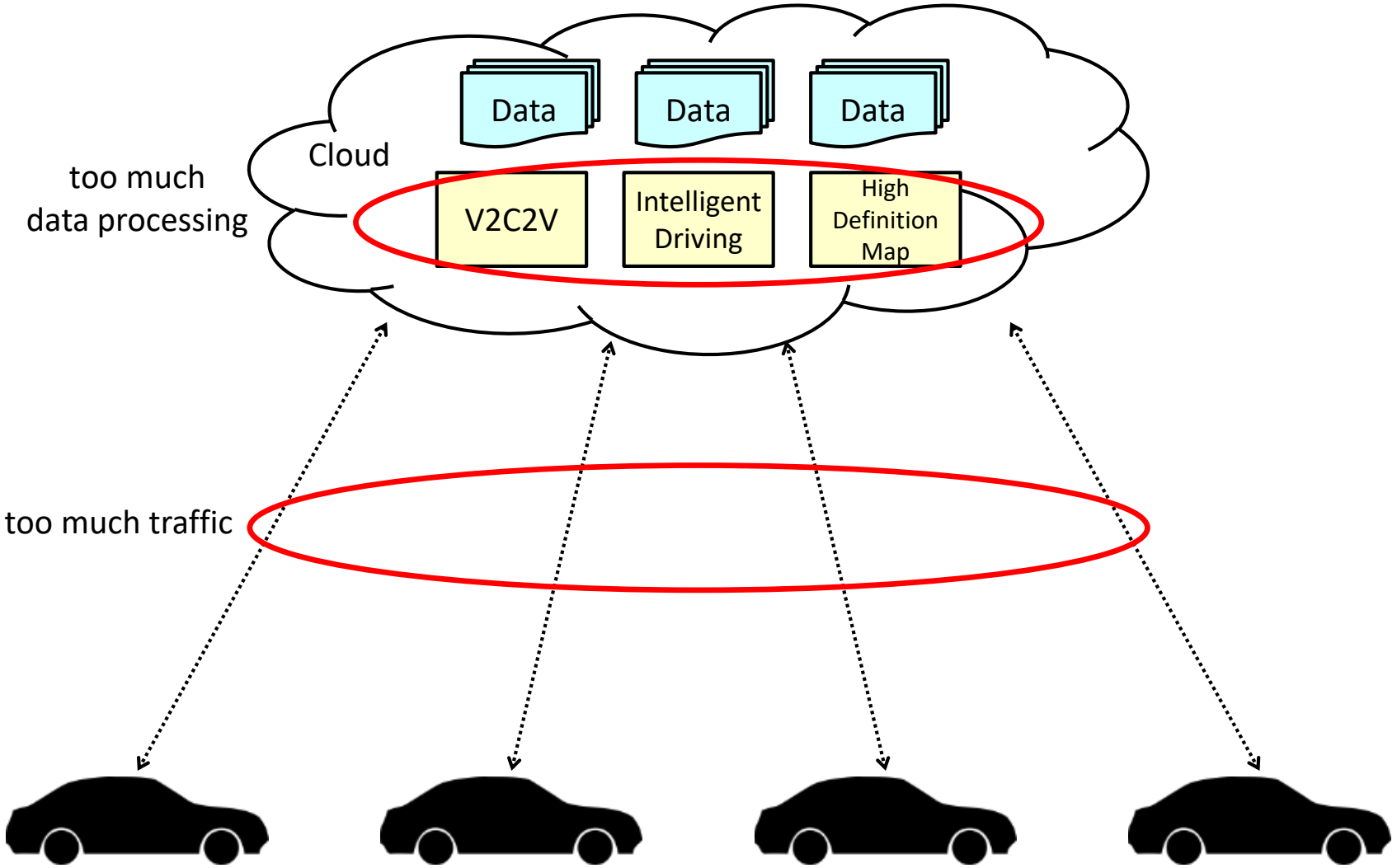


One Example Solution

- Decide task allocation and assign priorities to tasks on ECUs and messages on the network
- Satisfy timing constraints for tasks, signals, and paths

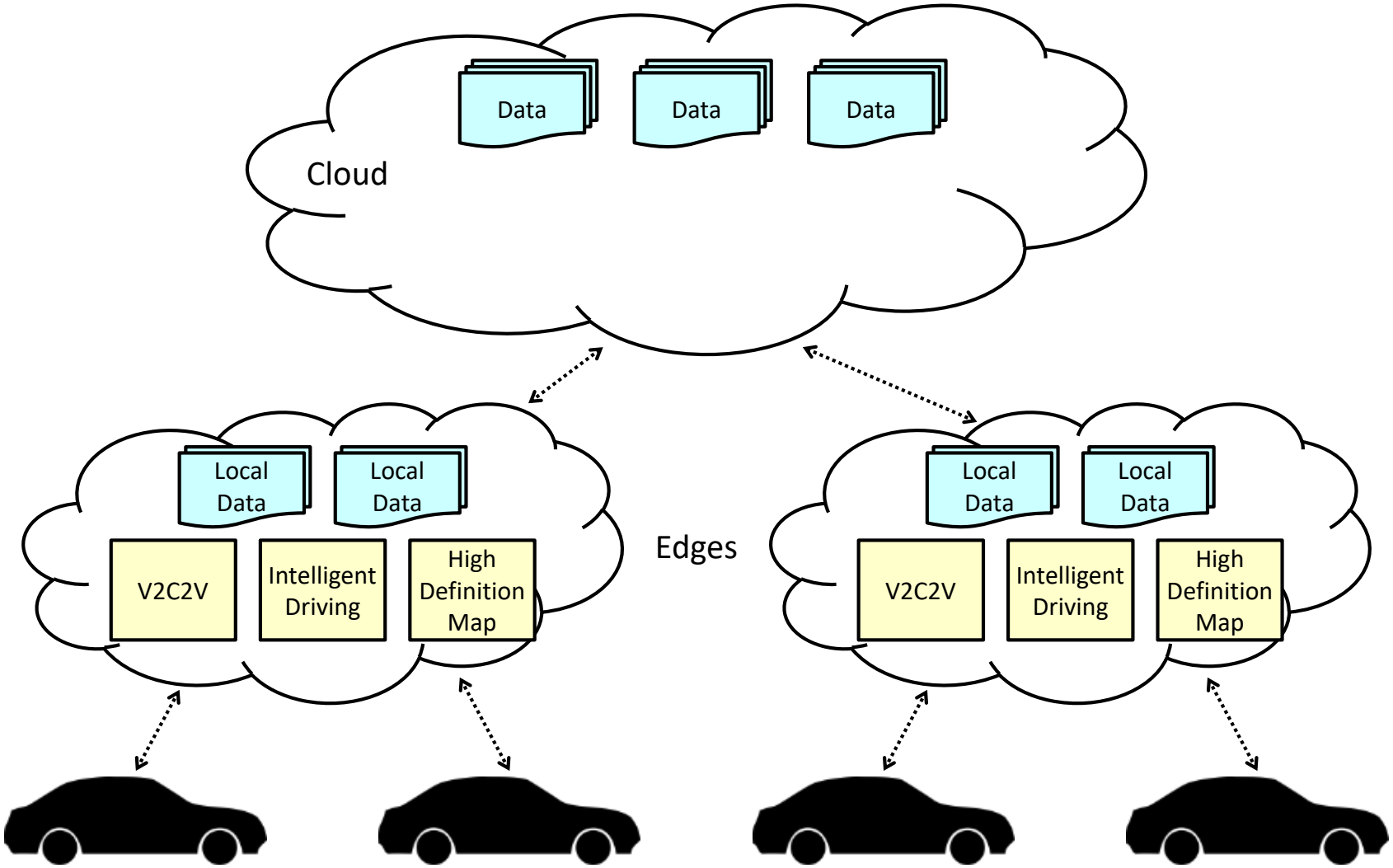


Edge Computing (1/2)



From Automotive Edge Computing Consortium

Edge Computing (2/2)



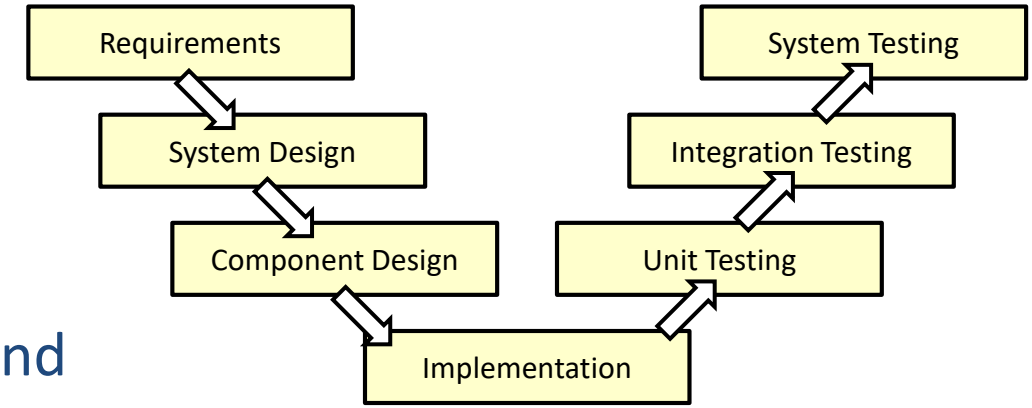
From Automotive Edge Computing Consortium

Outline

#1 Placement	**#2** **Verification**
#3 Software Integrity	#4 Security-Aware Design and Analysis

Motivations

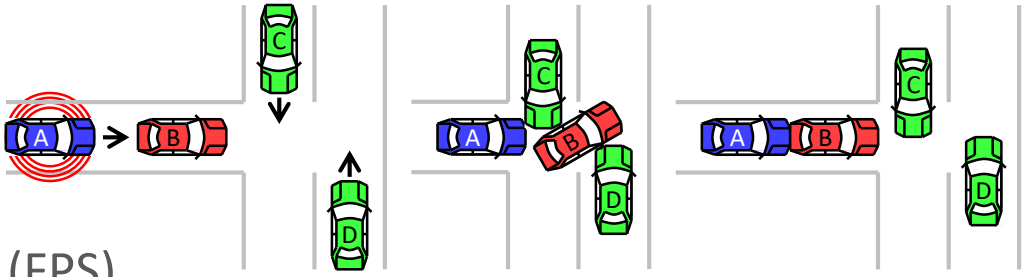
- The traditional system development process is the V-model
  - An OEM defines the specifications of components
  - Suppliers implement those components



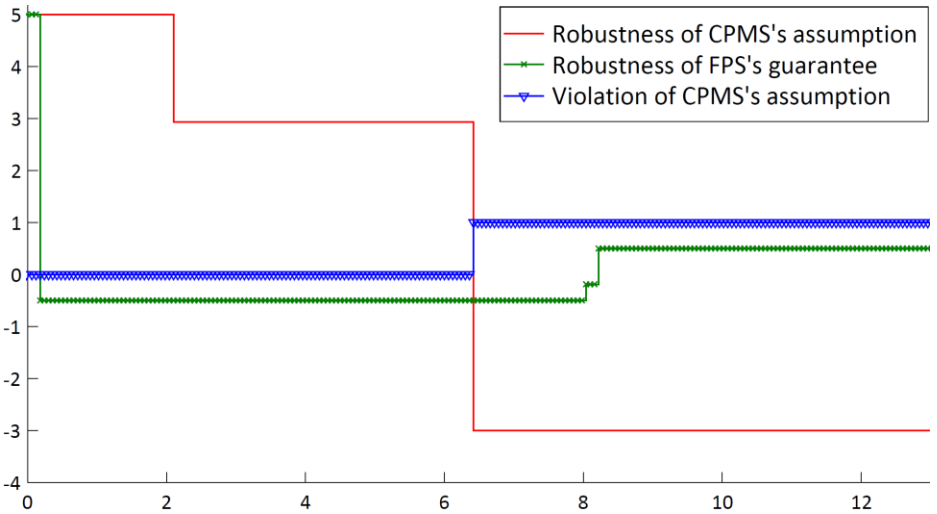
- Formal verification can be applied to design models and implementations
  - However, its scalability limits its applicability to systems of high complexity
- Runtime monitoring becomes a practical alternative
  - Detect and notify when there is any specification or requirement violation during runtime

Case Study

- Integration of two systems
  - Cooperative Pile-up Mitigation System (CPMS)
  - False-start Prevention System (FPS)



- Property specification language and automation tool
  - Signal Temporal Logic (STL)
    - Extend Linear Temporal Logic (LTL) to specify properties over real time
  - Breach [Donze '10]
    - Given a STL formula, synthesize an online monitor as a C++ program or a MATLAB S-function which can be realized as a Simulink block



- An assumption violation of CPMS is detected!

Outline

#1 Placement	#2 Verification
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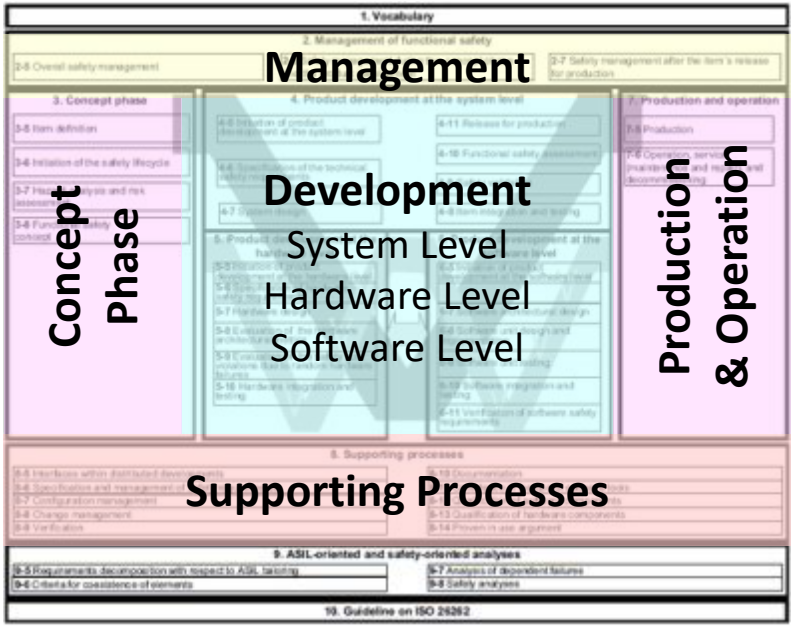
ISO 26262

- ISO 26262 is recognized as the state-of-the-art standard for functional safety of automotive systems
- Examples
  - Some software structures are NOT recommended for highest Safety Integrity Level (SIL)
    - Dynamic objects and variables
    - Multiple uses of variable names
    - Implicit type conversions
    - Unconditional jumps
    - Recursions

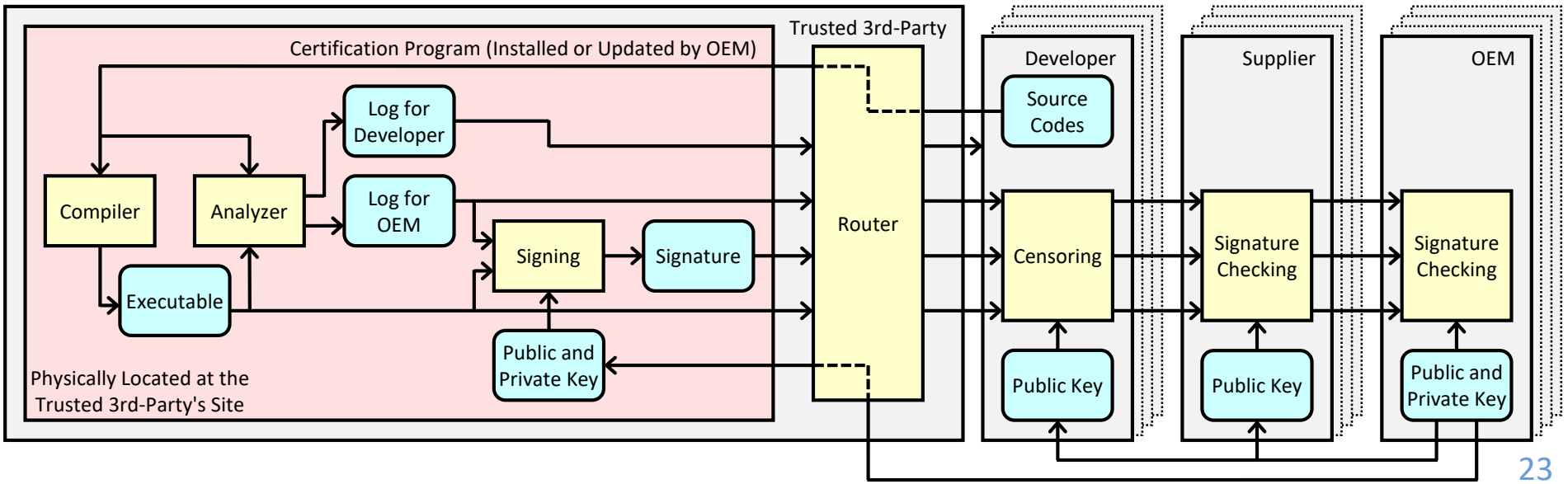


Motivations

- A potential conflict between certification issuers (e.g., OEM) and software suppliers (developers)
  - A certification process represents a systematic way to inspect the source codes
  - Some source codes of software suppliers (developers) are confidential
- Desired properties
  - Authenticity
    - Only authenticated results from compilers and analysis tools (verification, simulation, and/or testing) are considered by the certification issuers
  - Confidentiality
    - Sensitive source codes of the software suppliers and developers are not released to certification issuers

Certification Protocol

- Trusted third-party
  - Run a certification program which consists of a compiler and an analyzer
  - Maintain a router which controls the input and the output
- Certification program
  - All of the compiler, the analyzer, and the private key are updated by the OEM
  - The updating process must be unidirectional to guarantee confidentiality
- Router
  - Only the corresponding developer can be the receiver

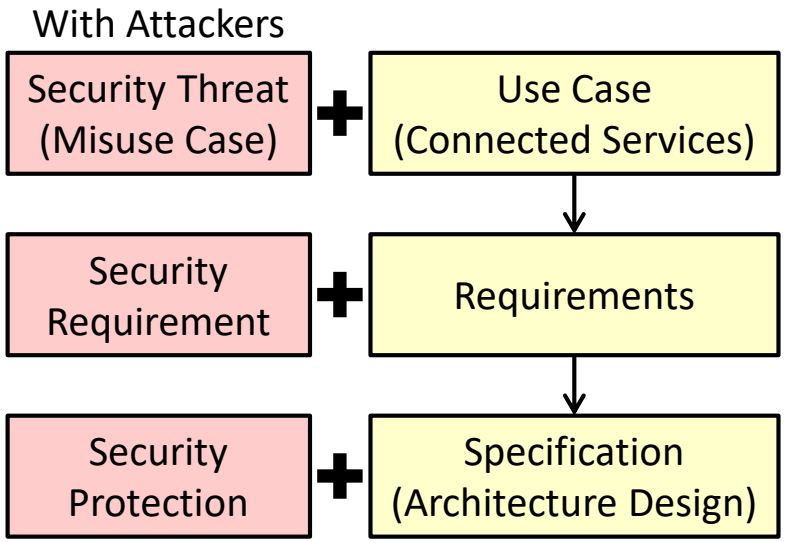


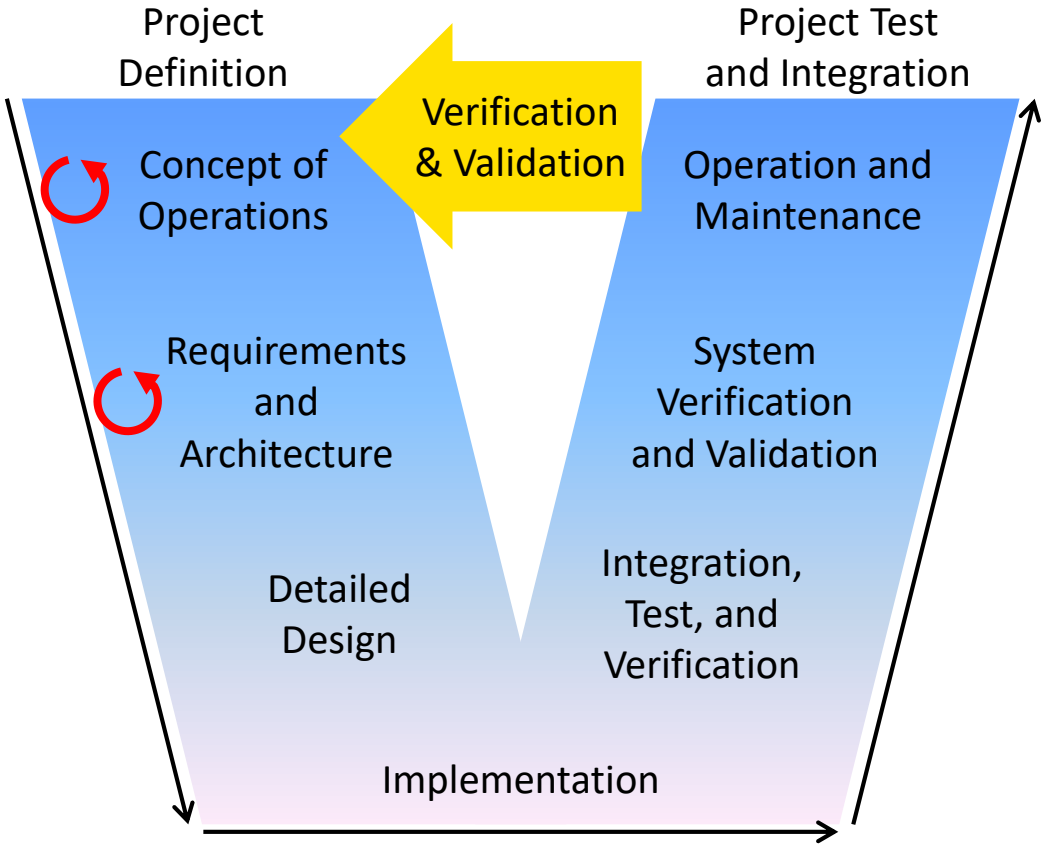
Outline

#1 Placement	#2 Verification
#3 Software Integrity	**#4** **Security-Aware Design and Analysis**

"Design Automation"

- Consider different design metrics
  - Safety, robustness, performance, security, etc.
- Assist system designers for early design decisions
  - More efficient process





https://en.wikipedia.org/wiki/V-Model_(software_development)

Security-Aware Design and Analysis

- Security is a rising concern, especially with connectivity

CBS News, Aug 19, 2014

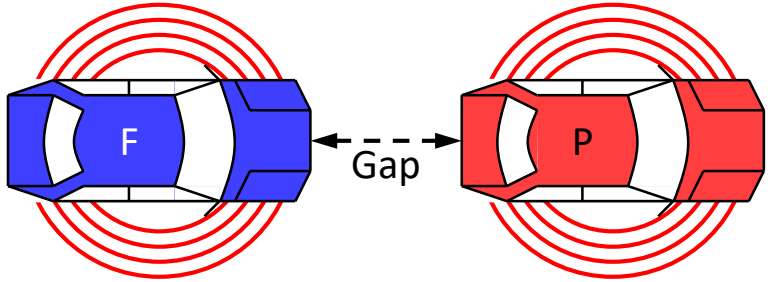
Live Free or Die Hard (Movie), 2007

- One hypothetical (but very likely) scenario
  - Design stage
    - Use the RSA algorithm (strong and famous) for encryption, decryption, and authentication!
  - Implementation stage
    - Computing units on vehicles cannot afford it… (security mechanisms are usually computation-intensive)
  - Result: redesign systems (how can we prevent this?)

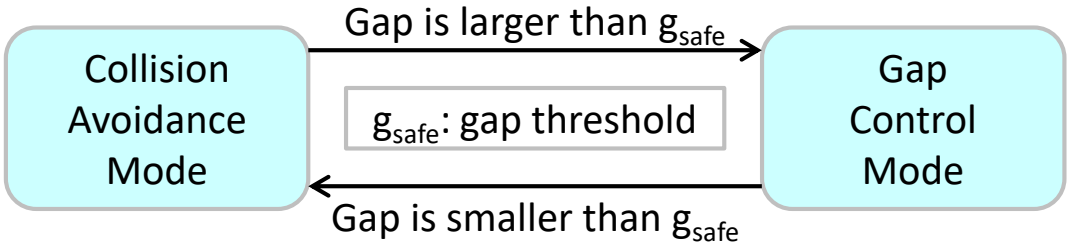
Cooperative Adaptive Cruise Control (CACC)

❑ Two CACC modes

- ➢ Gap control mode
  - The following vehicle (F) decides acceleration based on the gap, speeds, and accelerations of the two vehicles



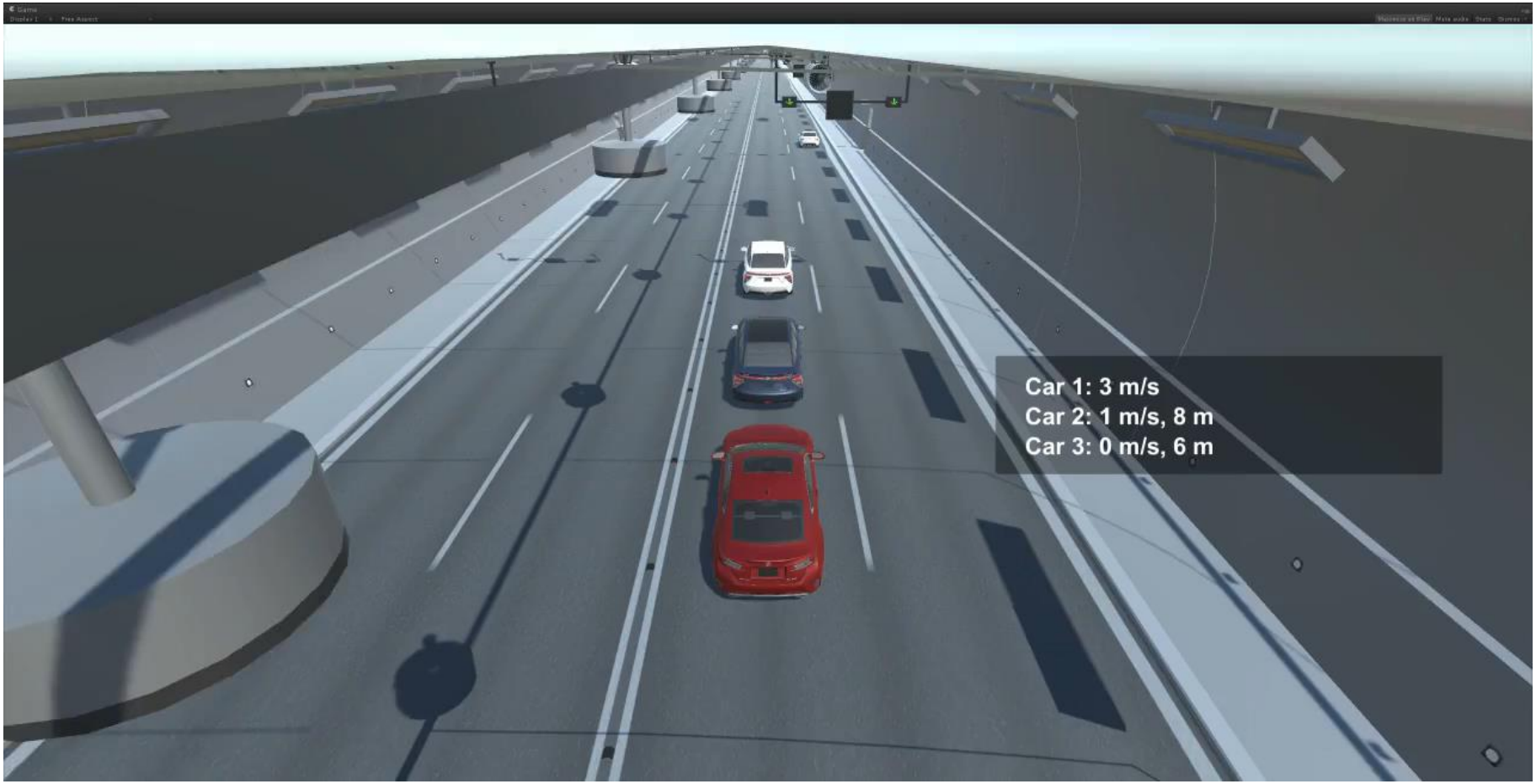
- ➢ Collision avoidance mode
  - The following vehicle (F) decelerates with its maximum deceleration



❑ Information sources

- ➢ Gap and speeds are obtained by sensors
- ➢ Accelerations are broadcasted with V2X messages

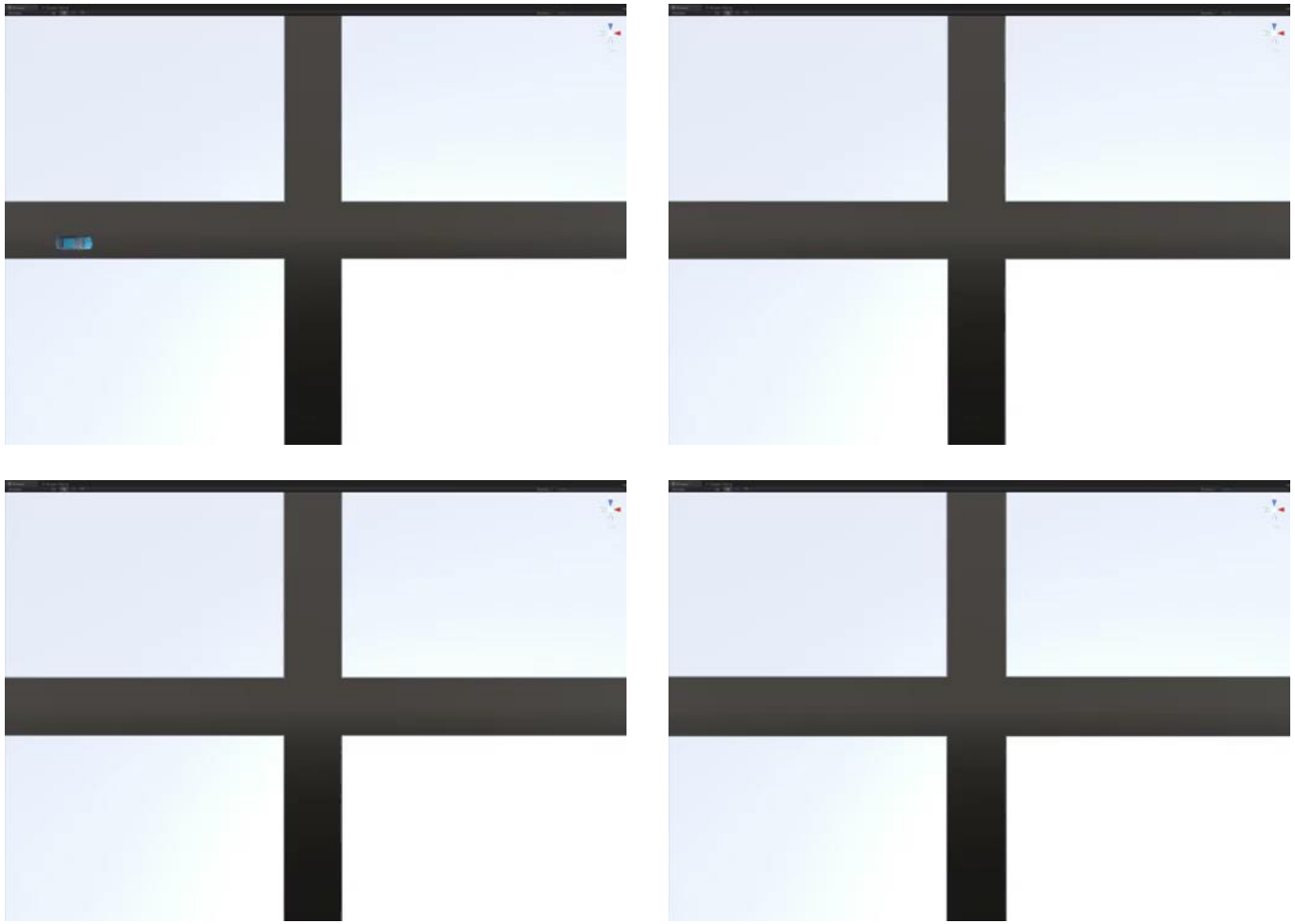
CACC with Jamming or Lying



Intersection Management

(With Jamming or Lying)

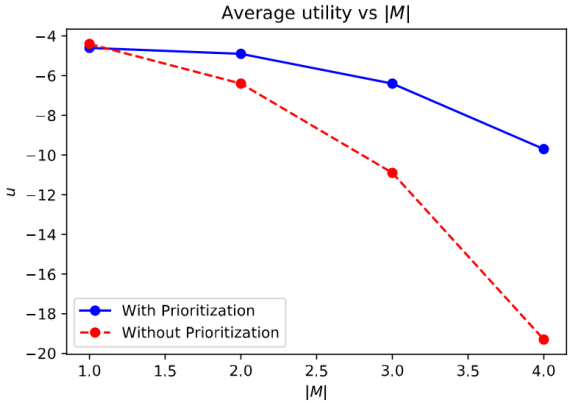
- An intersection manager receives requests from vehicles, schedule them, and sends confirmations to them

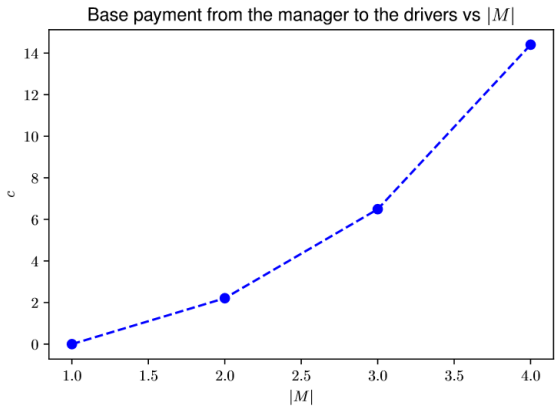


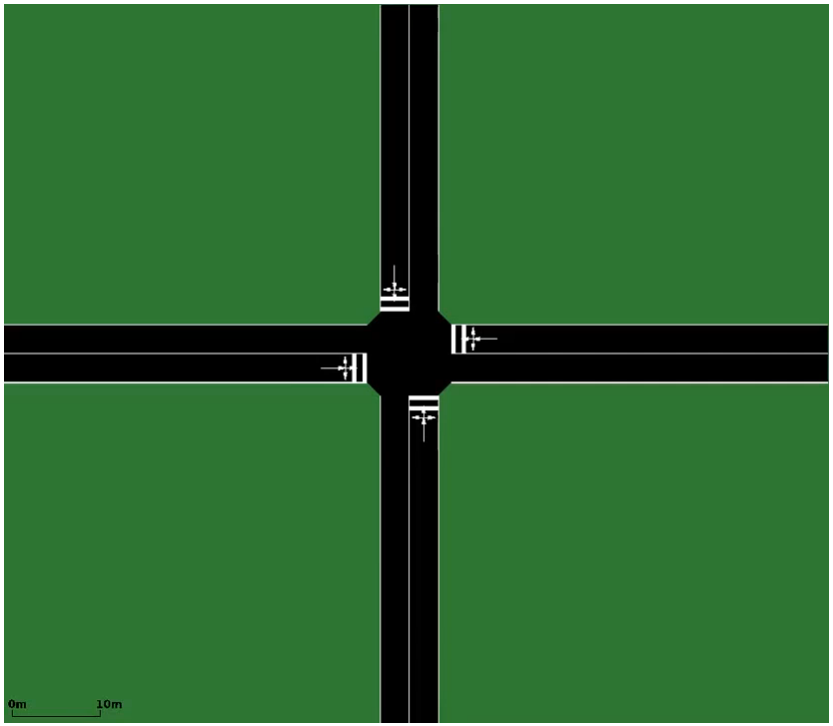
Intersection Management

(Payment-Based Solution against Lying)

- The payment-based approach supports prioritized intersection management where truthfulness is guaranteed
- An intersection becomes "more expensive" when there are more cars requesting the intersection







Summary

#1 **Placement**	**#2** **Verification**
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Q&A

Thank You!