Cooperative Systems for Traffic Safety:

Will Existing Wireless Access Technologies Meet the Communication Requirements?

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Cooperative Systems for Traffic Safety

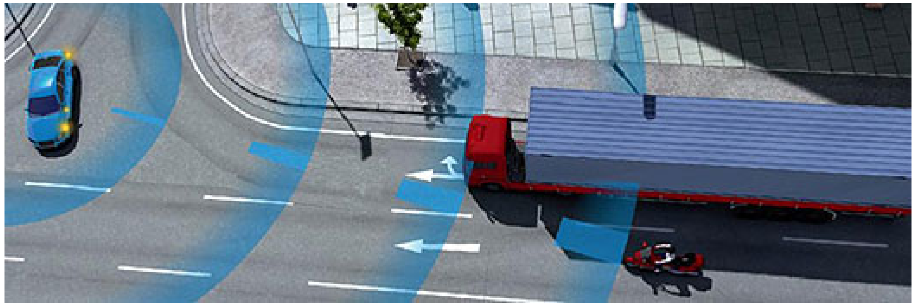
- Examples of traffic safety applications
- Typical communication requirements
- The implementation affects the quantitative requirements!
  – What should be communicated?
  – How is the information used?
  – How is system performance evaluated?
- Summary and suggested approach

Example Traffic Safety Applications

- CVIS: Enhanced Driver Awareness
- SAFESPOT: Extend the driver's "Safety Margin" to detect and prevent potential accidents
  - Overtaking Vehicle Warning
  - Forward Collision Warning
  - Critical Road Segment Assistance

Typical Communication Requirements

- Traffic safety applications relying on cooperative embedded systems have exceptionally challenging requirements:
  - Low-delay,
  - reliable,
  - scalable,
  - real-time communication



Source: CAR 2 CAR Communication Consortium

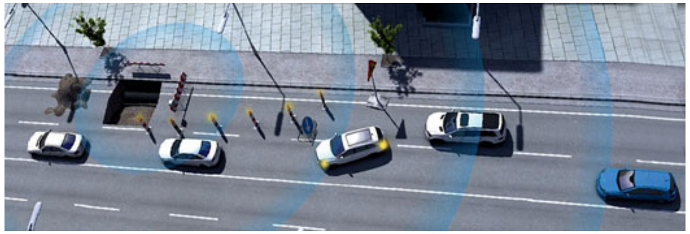
http://www.car-to-car.org

is to be provided in a harsh, dynamic environment.

- These requirements notably differ from those of most existing applications relying on wireless communications.

Reliable, Deadline Dependent Communication

- The wireless communications protocols available today enables **either** reliable communications with low error rate **or** time-critical communications with real-time constraints – **but not** integrated high levels of **both**:
  - **Voice** has real-time requirements but is relatively error tolerant.
  - **E-mailing** requires reliable communications but is delay tolerant.
  - **Control traffic** on a fieldbus has requirements on both reliability and real-time but the fieldbus is wired and centralized.
  - **Cellular networks** carrying data traffic provides reasonable guarantees on real-time and reliability, but coverage is needed, and the cellular structure introduces increased delay.



Source: CAR 2 CAR Communication Consortium
http://www.car-to-car.org

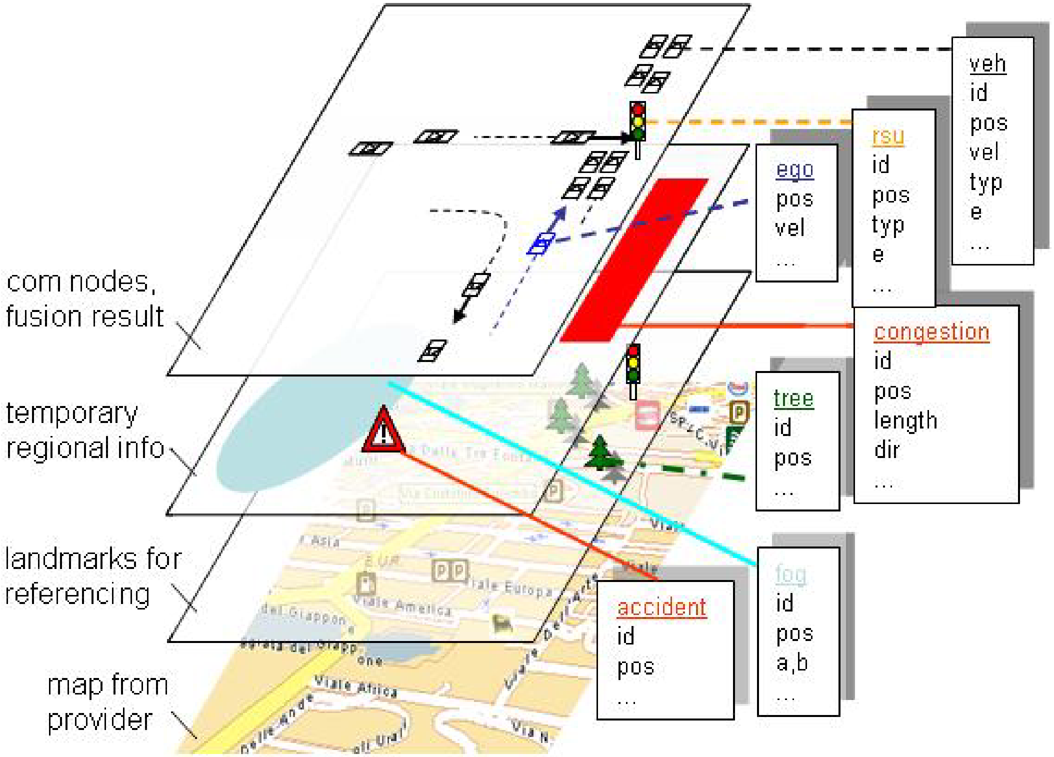
Qualitative Requirements

- So, how low-delay, reliable, and scalable, does the deadline dependent real-time communication need to be?
- Well, that depends…



Problem #1: What is to be communicated?

- How long are the messages?
- How often are something sent?
- What QoS requirements do the messages have?
- What happens if a message is lost?
- How many consecutive messages can be lost?



Source: SAFESPOT, http://www.safespot-eu.org/

Different Realizations

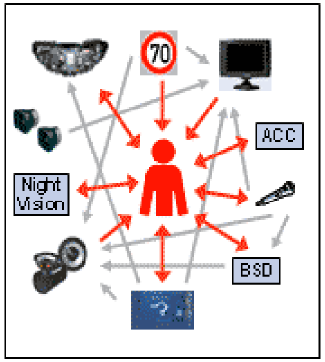
- **Hazard Warnings:** Information is communicated only in the event of a hazard. Event-driven messaging with requirements on very low delay and very high reliability (the hazard is imminent and the data is critical). However, the system is useful also at moderate penetration rates since it is simply an enhancement of existing sensors.
- **Cooperative Awareness:** Requires that all vehicles are equipped with a communication system and periodic time-triggered messages are broadcasted. Since the messages are repeated periodically and do not signal imminent hazard the requirements on delay and reliability are moderate. However, in order to avoid a system with invisible, mute vehicles, a very high penetration is likely needed
- **Cooperative Autonomous Driving:** Not only is this system required to warn or predict and advice – but also to act. Typically both periodic time-triggered and event-driven messages, requiring some sort of service differentiation between the two types of messages, and very likely close to 100% penetration will be needed.

Observation or Evaluation?

- The control loop that is using the communicated data consists of four steps: observation, evaluation, decision and action.
- The communicated messages could either be raw data (observation) or some level of refined data (evaluation) or even the actual driver intentions.
- Transmitting processed data is likely to required less bandwidth but higher penetration rate such that decisions are made based on the same information.
- When penetration increases, more and more processed data could be transmitted to compensate for the increase in required collective bandwidth.

Problem #2: How is the information used?

- What can the local dynamic map be used for? Warnings? Predictions? Advice?
- How trustworthy is the information?
- How do we make sure that the information indeed helps rather than confuses the driver?



Source: AIDE, http://www.aide-eu.org/

AIDE truck platform based on Volvo FH12

Reliability versus Autonomy

- An issue that greatly influences the requirements of the wireless communication is the selected level of autonomy.
- The more reliable the communication system is, the higher autonomy can be given to the application:
- ”Inform – Warn – Advice – Guide – Steer”

Problem #3: Do Cooperative Embedded Systems Offer Improvements?

- How do we know that safety is improved?
- How do we verify that these distributed systems function as intended?
- If something goes wrong – who's fault is it?
- Do people want this?

Validation and Verification

- Information theory has provided a scientific foundation for the development of both the internet and cellular phones. But:
  - performance limits of decentralized wireless networks are presently not known,
  - a central concept for information theory is capacity, characterized by the maximum reliable throughput between two mobile terminals
- In real-time communication systems, traditional performance measure throughput is of less importance the performance measure “deadline miss ratio” is instead used.
- However, even this performance measure needs to be redefined in due to the broadcast nature for both event-driven and time triggered realizations.
- Successful message reception should instead be defined as a function of the number of vehicles in communication range and interest range.

Summary and Suggested Approach

- The communication requirements depends on and changes with different realizations (e.g., event or time-triggered).
- The information can be used to: inform, warn, advice, guide or even steer. Raw or processed sensor data could be communicated all implying different requirements.
- The communication requirements should be matched to the performance measures and evaluated accordingly.
- *It is important for application software developers and communication experts to work closely together **continuously**, not only when defining and evaluating the communication requirements, but also when implementing the vehicular networks as well as during FOTs.*
- Example: If the reliability is too low for some types of road scenarios, the level of autonomy could be temporarily reduced, e.g., from guide and advice to warn and inform.