MOTIVATION

- Majority of human population live in cities – urbanisation
- More than 60 metropolitan with population > 5 million
  - Many will be driving cars, and the products they consume will be arriving in trucks – making gridlock the norm.
- What might the future hold?
  - Transportation infrastructure and management approaches can't handle the world's traffic.
  - In Australia, the latest estimates put the cost of time spent sitting in traffic at $11.1 billion annually.
  - In USA ~2.8b gallons of gas wasted sitting in traffic costing ~$83b
Traffic congestion is a major cause of lost productivity

- In Australia avoidable productivity cost of congestion of $9.4b in 2005 rising to $20.4b in 2020

Traffic congestion is a major cause of pollution.

- Land transport pollution accounts for around 13% of Australian Green House Gas emissions (National Greenhouse Accounts).

Safety

- In Australia - annual national road toll is around 1,300 deaths and 32,500 serious injuries.
- Approximately 40,000 people are killed each year and ~1.7 million with critical injuries in Europe
- Annual cost related to traffic accidents total roughly US$1 trillion
Beijing, Mexico City, Moscow, New Delhi – very high economic & emotional toll than most of the Western world cities

Source: IBM
**WHAT CAN WE DO?**

- **Public transport**: extension and improvement of public transport networks, parking space management, city logistics, low-speed zones, etc.
- **Traffic management**: integrated computer based control systems, traffic safety
- **Zero emission vehicles**: electrical vehicles
- **Air quality and noise pollution**: Usage of traffic management solutions in connection with air monitoring networks to improve air quality and noise abatement
- **Logistics**: Application of ICT solutions to freight traffic to reduce pollution and congestion, optimize delivery times and limit transport costs
- **Urban planning**: Monitoring of flows and planning of building and activities (e.g. malls, public buildings, etc.) in order to prevent congestion, reduce traffic and facilitate the use of public transport
- **Smart Grids**: Connection between energy networks and transport networks to ensure availability of alternate fuels, pollution control, etc.
- **Communication Tools**: innovative communication tools to improve ridership on public transport, traffic, etc.
Way Forward

Better use of existing Road capacity

“Cooperative Intelligent Transport Systems”
What is Cooperative Intelligent Transport Systems?

Advanced INFORMATION & COMMUNICATIONS TECHNOLOGIES used to enhance safety, improve mobility, support commerce, and help sustain the environment.

- Transport Safety
- Transport Productivity
- Travel Reliability
- Health & Safety
- Environmental Performance
- Informed Travel Choices
- Social Equity
- Network Operation & Resilience
- etc.

**Addressing multi-modal**
COOPERATIVE MOBILITY CONCEPT

- Anticipating by communication
  - Efficient use of roads during heavy traffic
  - Information on road conditions and traffic flow
  - Information on behaviour of other road users

- Supported by cooperative technology
  - Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication
  - Real-time personal warning and advising
CO-OPERATIVE INTELLIGENT TRANSPORT SYSTEMS TO IMPROVE SAFETY AT LEVEL CROSSINGS
LEVEL CROSSING COLLISIONS IN AUSTRALIA (2000 – 2009)

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Public road</th>
<th></th>
<th>Private road</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active</td>
<td>Passive</td>
<td>Active</td>
<td>Passive</td>
<td></td>
</tr>
<tr>
<td>Number of collisions</td>
<td>356</td>
<td>248</td>
<td>27</td>
<td>64</td>
<td>695</td>
</tr>
<tr>
<td>Number of people fatally injured</td>
<td>58</td>
<td>35</td>
<td>0</td>
<td>4</td>
<td>97</td>
</tr>
</tbody>
</table>

- Over 70 fatalities (1997 – 2002)

Source: ITSR
# Death and Injury by Category

Europe (2011)

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of persons</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Killed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passengers, Employees, Other, Total</td>
<td></td>
</tr>
<tr>
<td>Collisions</td>
<td>9, 3, 3, 15</td>
<td></td>
</tr>
<tr>
<td>Derailments</td>
<td>2, 2, 0, 4</td>
<td></td>
</tr>
<tr>
<td>Accidents involving level-crossings</td>
<td>6, 0, 311, 317</td>
<td></td>
</tr>
<tr>
<td>Accidents to persons caused by rolling stock in motion</td>
<td>22, 25, 856, 903</td>
<td></td>
</tr>
<tr>
<td>Fires in rolling stock</td>
<td>0, 0, 0, 0</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>0, 1, 2, 3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39, 31, 1172, 1242</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seriously Injured</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passengers, Employees, Other, Total</td>
<td></td>
</tr>
<tr>
<td>Collisions</td>
<td>33, 11, 5, 49</td>
<td></td>
</tr>
<tr>
<td>Derailments</td>
<td>43, 2, 0, 45</td>
<td></td>
</tr>
<tr>
<td>Accidents involving level-crossings</td>
<td>24, 14, 291, 329</td>
<td></td>
</tr>
<tr>
<td>Accidents to persons caused by rolling stock in motion</td>
<td>123, 36, 453, 612</td>
<td></td>
</tr>
<tr>
<td>Fires in rolling stock</td>
<td>0, 0, 0, 0</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>6, 20, 22, 48</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>229, 83, 771, 1083</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td></td>
<td>268, 114, 1943, 2325</td>
<td></td>
</tr>
</tbody>
</table>

Source: Eurostat
NEED FOR A COMPREHENSIVE SOLUTION

Causes include
- lack of awareness of an on-coming train
- unintended road user error
- driver behaviour and other human factors

Aust. Government Recommendations
- **State Government (Dec 2008)**
  - Adopt new developing technologies such as ITS
  - Govt. to coordinate support to develop, trial and adopt ITS
  - Trial, promote/encourage use of ITS at rail-road interface
- **Federal Government (June 2009)**
  - Gov. to support ITS research to speed the implementation
  - Research into feasibility of cut-in warning systems
Vehicle safety research is shifting its focus towards crash avoidance and collision mitigation.

Traditional sensors, like radars, have the following limitations:

- Limited range (sense immediate vehicles)
- Limited Field of View (FOV)
- Expensive

Cooperative Intelligent Transport Systems using wireless comm. (DSRC) for vehicle safety, mobility and commercial apps.

“360 Degrees Driver Situation Awareness” using wireless comm.
WHY DSRC?

- International standard for wireless vehicular communication at 5.8/5.9 GHz
- Licensed band operation
- 7 channels (10 MHz each) for supporting safety and non-safety applications
- Outdoor high-speed vehicle applications
- Cooperative safety system
  - Passive ⇒ active
  - Reactive ⇒ preventative
COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS

- Vehicle-to-Vehicle Communications
- Vehicle-to-Infrastructure Communications
- Human-Machine Interface (human factors)

- Safety
  - Intersection collision avoidance
  - Cooperative collision warning
  - Traffic signal interface

- Mobility
  - Traffic congestion management
  - Traffic signal control and management
  - Incident management

- Consumer & Commercial
  - Electronic payment
  - Fleet management
SAFETY APPLICATIONS

- Ability of V2V and V2I to address crash scenarios involving non-impaired drivers

V2V
- Forward Collisions
- Road Departure
- Intersection
- Lane Change/ Merge

82%

V2I
- Intersection
- Road Departure

16%

% of crash scenarios potentially addressed by technology

(NHTSA Assessment)
**SOLUTION**

- **Safety**
  - Intersection collision avoidance
  - **Cooperative collision warning**
  - Traffic signal interface

- **Mobility**
  - Traffic Congestion Management
  - Incident Management
  - in-vehicle signage/messaging
  - Traffic signal control & management

- **Consumer & Commercial**
  - Electronic payment
  - Fleet management
  - Information transfer

**Technology: DSRC**
- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
- Multi-hop

**Human Factors/Behavior**
CONCEPT OF THE SAFETY SOLUTION

Intelligent Transport Systems using 5.9 GHz DSRC Technology

Scenario: Vehicle approaching a level crossing
PARTNERS
Development of Scalable Simulation Platform for Level Crossings

- Specialised ITS Simulation platform for Rail-road crossings
- Development/Implementation of scalable simulation models
- Empirical analysis of typical interactions between rail and road traffic

Development of the ITS Demonstrator System

- Implementation of new algorithms for safety
- Implementation and tuning of new scalable HMI interfaces
- Testing, validation and optimisation before field trial

Field Trial

- Field trial with 100+ vehicles
- Installation in trains, trucks, cars and at rail-road crossings
- Data collection and analysis - refining algorithms/implementations
ESSE Framework (Linux 2.6.18 - Centos, x86_64 Architecture)

HPC Messaging Library
Open MPI (with InfiniBand Support and Gigabit Ethernet)

Parallel Computing Cluster

Simulation/Scene Builder Setup
“Drag Drop” Entity Selection (Vehicle/Driver/Map)
Configurable Parameters
Visualisation/Animation
Design of Experiments (DoE)

Configuration Data

Simulator Elements
XML Configuration Parser
Routing/Congestion Algorithms
Global Positioning System (GPS)
Mechanical Solver (Vehicles)
Behavioral Models (Drivers)
Following Model (Vehicles)
DSRC PHY/MAC
DSRC Context Perception
HMI Messaging

Traced Statistics

ESSE Framework
(Linux 2.6.18 - Centos, x86_64 Architecture)

Simulator Software

Extensible Configuration Files
Scene (Map)
Vehicle Characteristics
Driver Characteristics
HMI Messages
DSRC Radio (PHY)
DSRC MAC
GPS etc.

Default Config.

Custom Config.

Scene (Map)

Vehicle Characteristics

Driver Characteristics

HMI Messages

DSRC Radio (PHY)

DSRC MAC

GPS etc.

Exchange Information

Hardware Platform

HPC Messaging Library
Open MPI (with InfiniBand Support and Gigabit Ethernet)

Parallel Computing Cluster

“Drag Drop” Entity Selection (Vehicle/Driver/Map)
Configurable Parameters
Visualisation/Animation
Design of Experiments (DoE)
**DSRC Functionality**
- CCH Operation (max higher power for RSU and Train)
- T2V and T2I-I2V for train messaging
- V2V BSM send on sync (network performance)

**Mapping & Context Perception**
- Auto-positioning and map interpolation
- Context perception for Head/Tail detection and trajectory estimation (V2V/V2I)
- Intelligent remote dead-reckoning
- Crossing safety detection

**Warning algorithm**
- Train critical position detection
- Intersection collision time calculation
- Extended NHTSA Collision Avoidance algorithm

**System Software**
- Logging events and packet information
- System error auto-detection and recovery functions
Staged intelligent warnings (direct path)

- First warning: presence of train on current path
- Higher levels: triggered through algorithm calculations (NHTSA + presentation time, reaction time, safety margins)
- Combination of audio and video to produce perceptual cascading effect
- Volume of sound and intrusiveness of visual alert increase with level of urgency

Staged intelligent warnings (in-direct path)

- Higher level audio-visual alerts are only triggered as driver enters a direct path to the level crossing
- All alerts extinguish as soon as vehicle has cleared the crossing or is heading away from crossing
# Field Trials Scenarios

<table>
<thead>
<tr>
<th>Orchestration Scenarios</th>
<th>Rural (7 vehicles)</th>
<th>Urban 1 (70 vehicles)</th>
<th>Urban 2 (30 vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Mass vehicles stationary/moving</strong></td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Road vehicles approach perpendicular to crossing</strong></td>
<td>X (40-100 km/h)</td>
<td>X (30-60 km/h)</td>
<td>X (30-60 km/h)</td>
</tr>
<tr>
<td><strong>3. Road vehicles approach parallel to crossing</strong></td>
<td>X (40-100 km/h)</td>
<td>X (30-50 km/h)</td>
<td>X (30-50 km/h)</td>
</tr>
<tr>
<td><strong>4. Road vehicles turn away from crossing</strong> (from direct or indirect approach)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>5. Road vehicles turn in towards crossing</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Special Scenarios**

- **Hard deceleration on high urgency alert** | X |
- **Obtuse approach (V2V)** | X |
- LOS NLOS radio propagation in city area
- Heavy channel congestion and interference
- Radio fading and path loss in high-building area
- Level-crossing warning threshold in city area
- Complex indirect path operations
- Heavy-traffic and complex road driving habits
- Driving habits at highly controlled crossing
FIELD TRIALS
RESULTS AND DATA ANALYSIS - HIGHETT
DIRECT APPROACH

Perpendicular Approach
HIGHETT SHOWING LOS QUALITY AND CONNECTIVITY
### Factors Affecting Connectivity at Trial Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Street</th>
<th>&gt; 90%</th>
<th>50%</th>
<th>&lt; 10%</th>
<th>Building Density</th>
<th>Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dingee</td>
<td>Dingee Rd</td>
<td>0-200m</td>
<td>700m</td>
<td>&gt; 1050m</td>
<td>Low</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>Queen St</td>
<td>0-250m</td>
<td>1050m</td>
<td>&gt; 1700m</td>
<td>Low</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>King St</td>
<td>0-200m</td>
<td>600m</td>
<td>&gt; 700m</td>
<td>Low</td>
<td>Flat</td>
</tr>
<tr>
<td>Highett</td>
<td>Highett Rd (West)</td>
<td>0-210m</td>
<td>380m</td>
<td>&gt; 410m</td>
<td>Medium</td>
<td>Lower than RSU</td>
</tr>
<tr>
<td></td>
<td>Highett Rd (East)</td>
<td>0-100m</td>
<td>150m</td>
<td>&gt; 220m</td>
<td>High</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>Railway Parade</td>
<td>0-110m</td>
<td>130m</td>
<td>&gt; 170m</td>
<td>Medium</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>Graham Rd</td>
<td>0-220m</td>
<td>320m</td>
<td>NA</td>
<td>Medium</td>
<td>Flat</td>
</tr>
<tr>
<td>Cheltenham</td>
<td>Park Rd (West)</td>
<td>0-130m</td>
<td>180m</td>
<td>&gt; 240m</td>
<td>Medium</td>
<td>Much Higher than RSU</td>
</tr>
<tr>
<td></td>
<td>Park Rd (East)</td>
<td>0-360m</td>
<td>NA</td>
<td>NA</td>
<td>High</td>
<td>Flat</td>
</tr>
</tbody>
</table>

- Connectivity at **urban sites** (Highett and Cheltenham) is significantly different from that of the **rural site** (Dingee).
- **LOS** quality is clearly the **primary factor** that affects the connectivity.
- **Building density** and **terrain** also notably affect the connectivity.
**Participant self-reports of Startled**

- **Driver Responses**
  - Rural trial
  - Urban trial 1
  - Urban trial 2
  - Generic trial

**Participant self-reports of Distraction**

- **Driver Responses**
  - Rural trial
  - Urban trial 1
  - Urban trial 2
  - Generic trial
ROAD MAP AND COMMERCIALIZATION

Queensland Large Scale Deployment Trial

“Smart City Test Bed” Shanghai, China

Research

Victorian Trial
TRAM NETWORK

- Ongoing interest in improving safety record and reduction of tram-to-tram and tram-to-road vehicles/pedestrian collisions

- Commercial & safety benefits
  - Reduce accident rates and tram repair costs of franchise:
    - Reduced tram to tram accidents
    - Reduced tram to road vehicle accidents as the road fleet commences utilising the DSRC capability
    - Reduced tram to pedestrian accidents

- Operational applications
  - Speed restrictions, forced stops, other
Possible Trial sites
- Bourke-Spencer
- Swanston-Flinders

Collision Avoidance
- Tram-to-Tram
- Tram-to-Vehicle
- Tram-to-Pedestrian
- Speed restrictions
- etc.

Modelling
- Environment
- Trams
- Communication Channel
- T2T, T2V, T2I, etc
- HMI

HMI – Safety messaging

Warning: Safe headway distance is 15 meters.
DEMONSTRATION AND LAUNCH VIDEO
Thank you

Centre for Technology Infusion

“Bringing ideas to Life”

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E: Jack.Singh@latrobe.edu.au