Hybrid Visible Light Communications in Intelligent Transportation Systems with Position Based Services

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Background

- Intelligent Transportation Systems (ITS) has been motivated by the need for reducing traffic congestion and offering better user experience in navigation and location-specific services.
- Recently, visible light communication (VLC) has drawn a lot of attention. ITS is one of its most important applications. Traffic lights have been used to control traffic flow and located at a particular place and rarely moved are competent to indicate and to supply the information about the surrounding.
- Research on ITS using VLC is raised by the developments of light emitting diodes (LEDs) which have permitted the replacement of the conventional incandescent-based traffic lights. The main advantages of LED-based traffic lights are better power efficiency and much longer lamp life.

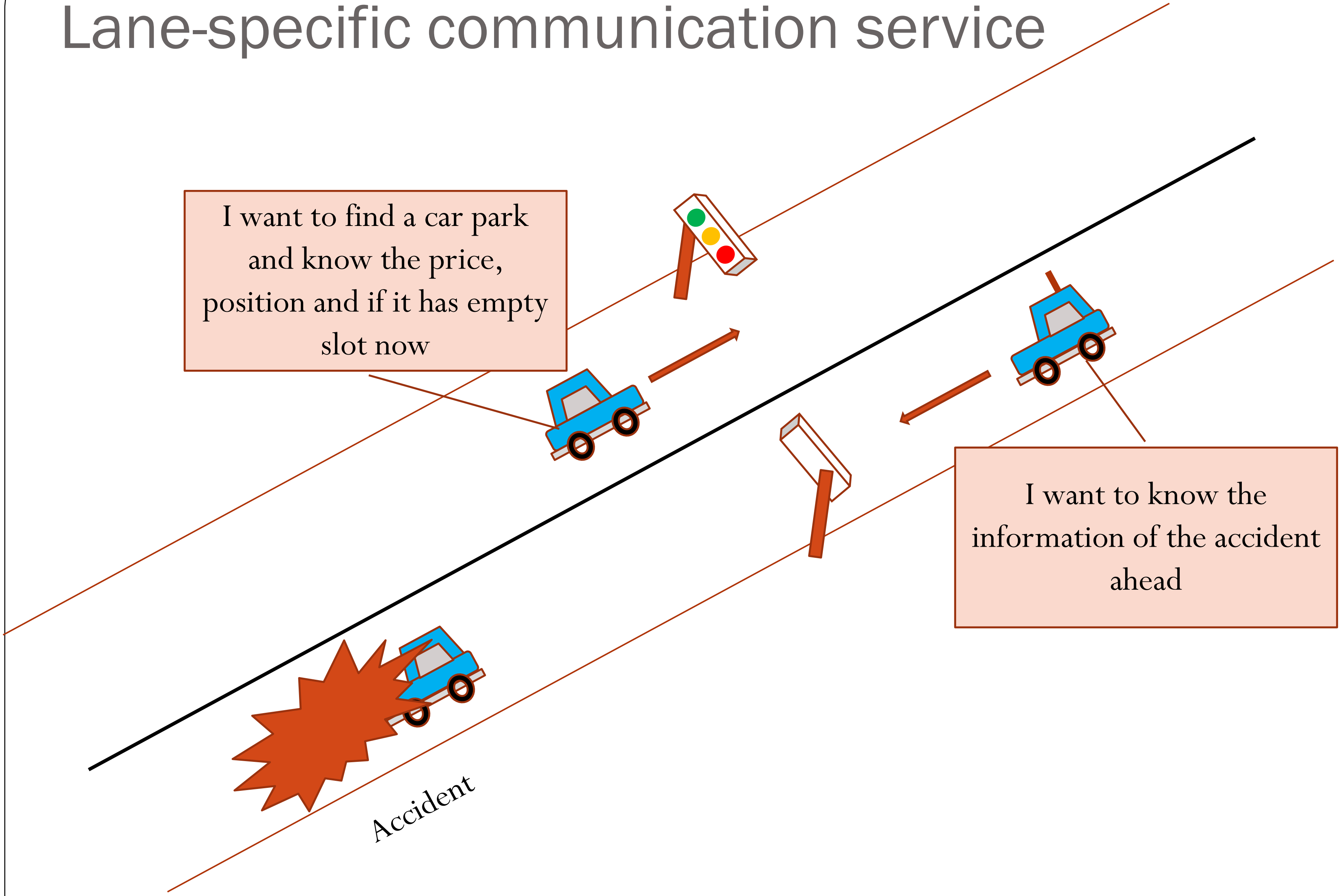
Why need hybrid optical and RF system

- Good directionality is a vital characteristic of optical communication. However, the optical channel suffers from weather conditions and interference from ambient lights and the optical link breaks off when obstacles appear. Therefore, the line of sight (LOS) scenario is the major usage in VLC

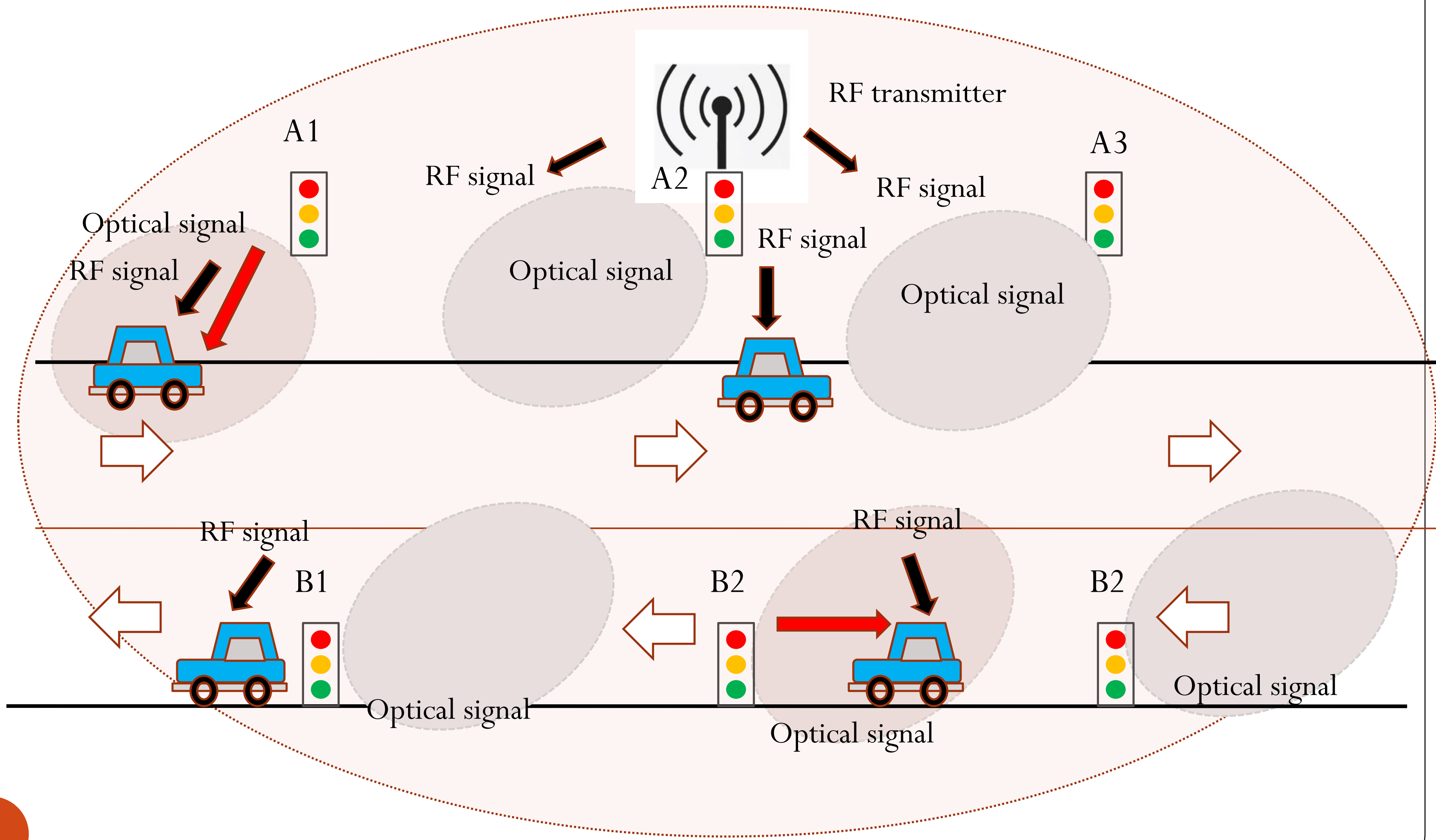
- On the other hand, radio waves have a high reliability but do not propagate only in the desired direction.

- In many situations, vehicle drivers want to have the information related to their lane only.

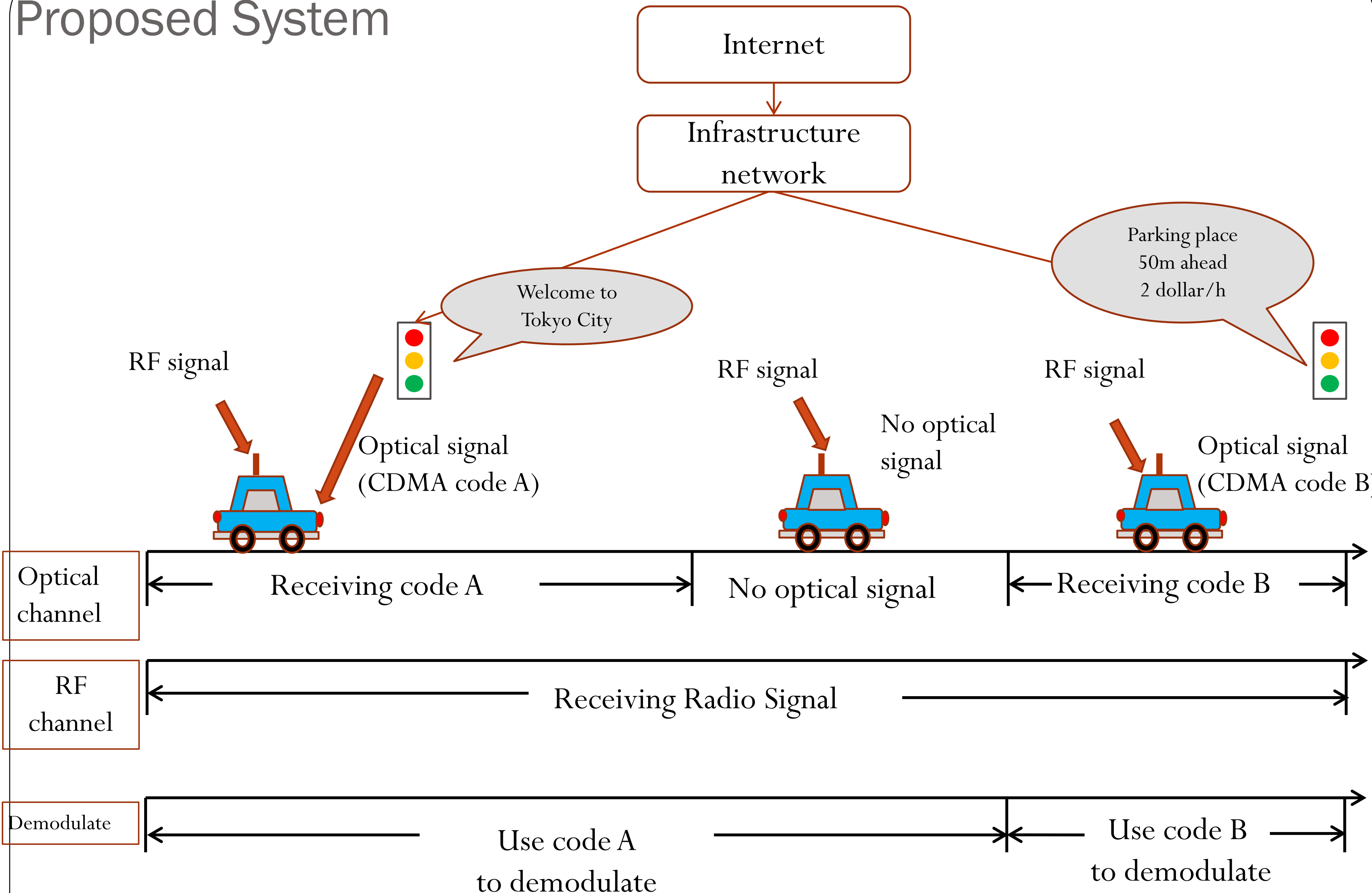
Lane-specific communication service



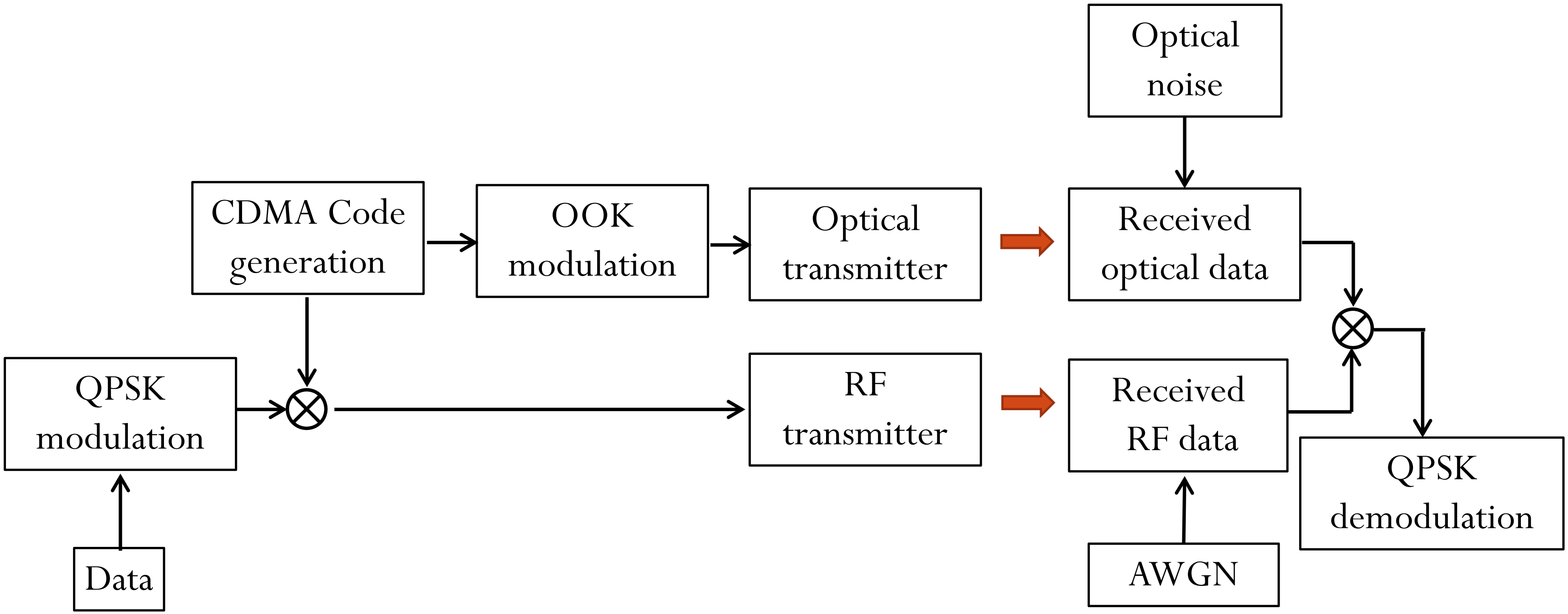
Proposed System



Proposed System



Block diagram for the hybrid CDMA system



The features of the proposed system

1) Hybrid deployment and utilization of two different communication technologies with complementary features.

2) Utilization of the directionality of conventional VLC systems to provide position based communication, and utilization of the reliability of radio communication to provide robust communication.

3) Applicable to not only ITS, but also other situations such as museums, shopping malls, and restaurants, etc.

The probability of error event

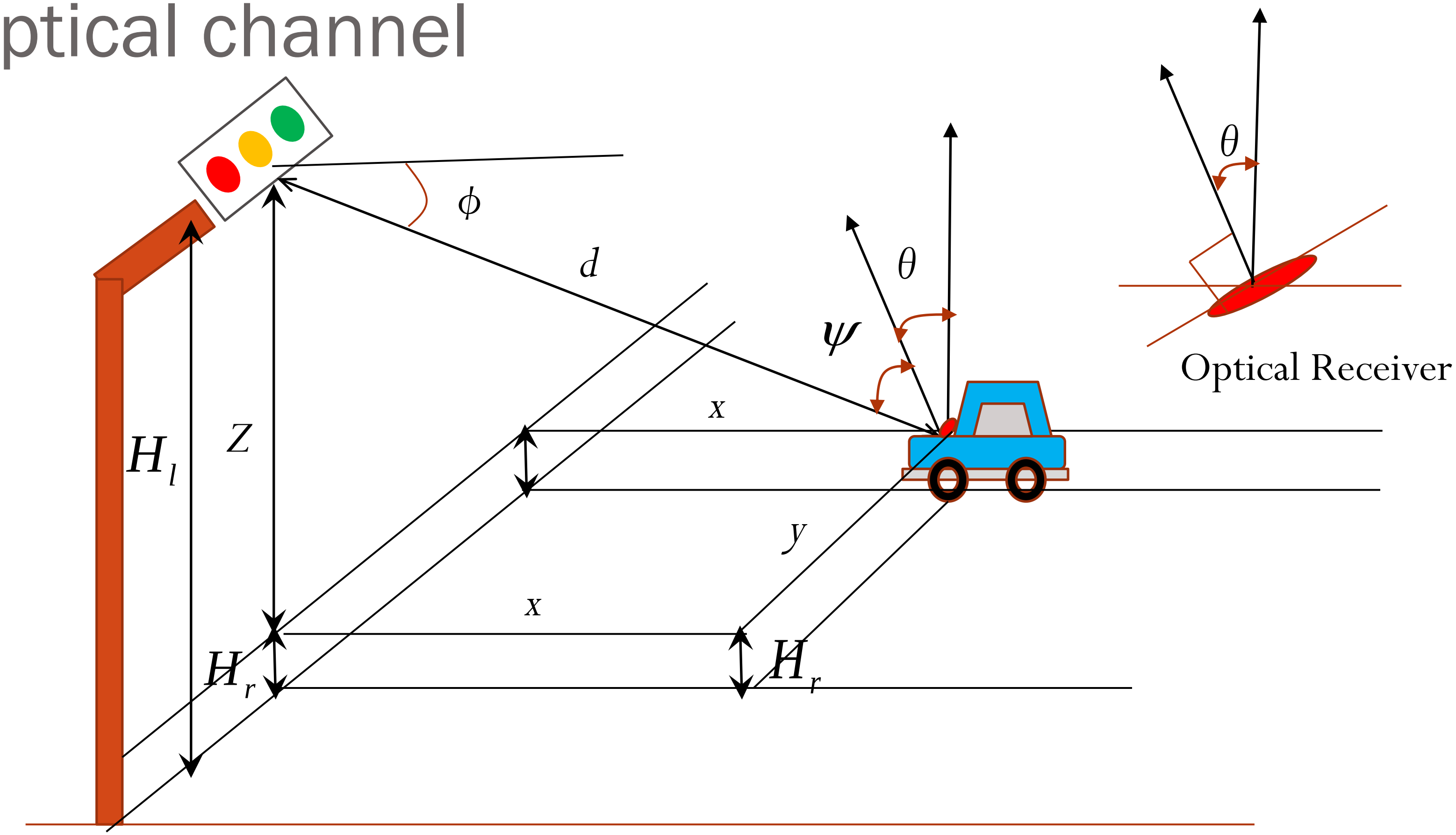
We define an error event as where the lane ID is incorrectly detected, or the frame error occurred when decoding the Traffic Information.

Mathematically, the probability of error event can be written as:

$$P_{Error} = P_{IDE} + (1 - P_{IDE})P_{FE}$$

where P_{IDE} is the probability of the detection error of the Lane ID and P_{FE} is the probability of the frame error in decoding the Traffic Information.

Optical channel



The channel direct current (DC) gain is given by

$$H(0)=\begin{cases}\dfrac{(m+1)A}{2\pi d^2}\cos^m(\phi)T_s(\psi)g(\psi)\cos(\psi), 0\le\psi\le\psi_c\\ 0,\psi\ge\psi_c\end{cases}$$

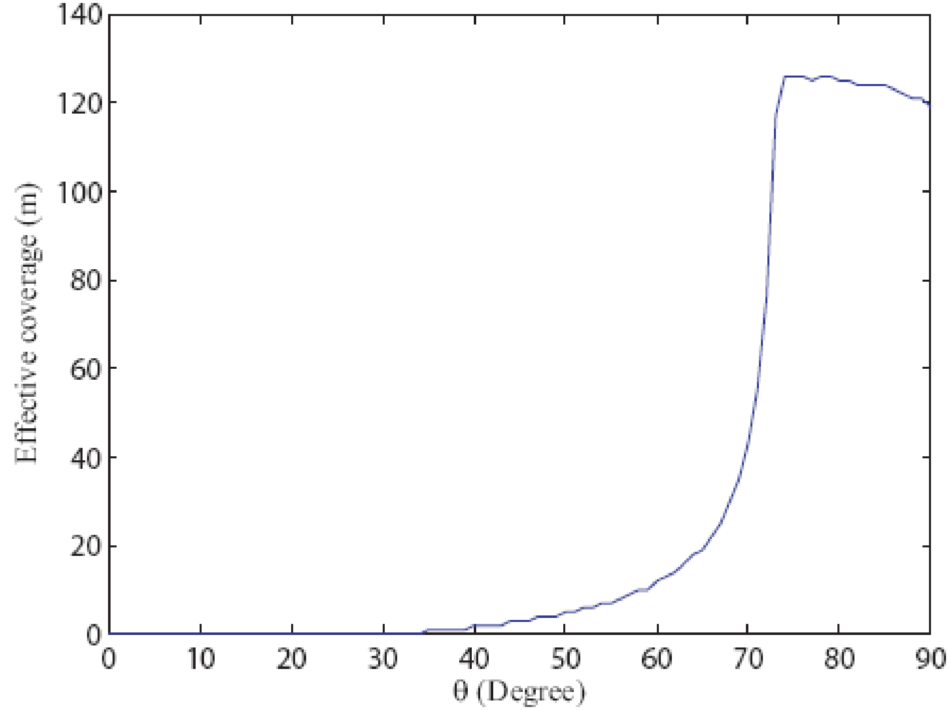
Where A is the detector physical area of a photodiode (PD), *T(ψ)* is filter transmission in the receiver and *G(ψ)* is the concentrator (lens) gain in the receiver.

The effective coverage (The range of an area which can guarantee a reliable communication)

Here, for optical communication using OOK modulation, a minimum SNR of 13.*6dB (or a BER of* 10^{-6}*)* is required to maintain a reliable communication link

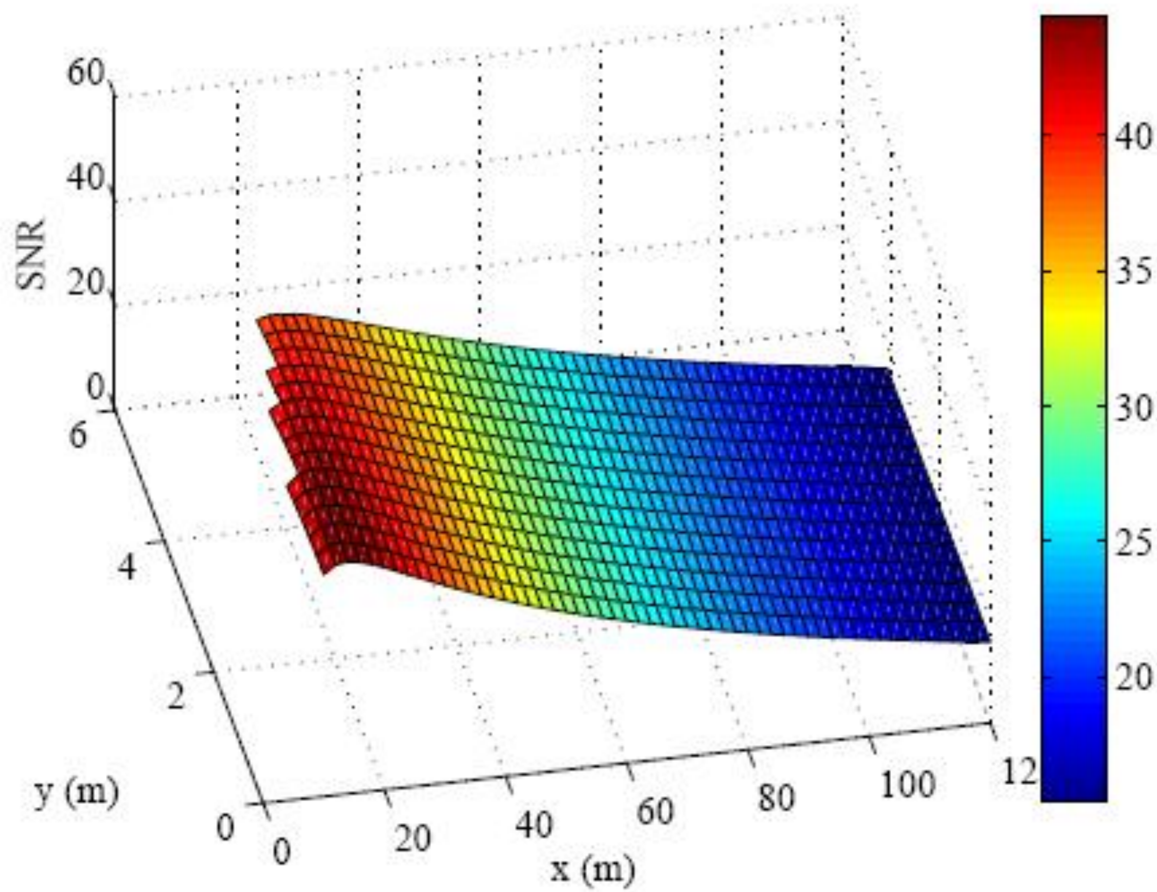
Parameters

Symbol	Quantity	Value
Length of Traffic Arm	L	$2.0(m)$
Height of Traffic Light	H_l	$5.3(m)$
Height of Receiver	H_r	$1.0(m)$
Difference between H_l and H_r	z	$4.3(m)$
Half-power Semiangle	$\phi_{1/2}$	$15°$
Detector Physical Area of APD	A	$0.79(cm^2)$
Gain of Optical Filter	$T_s(\psi)$	$300(K)$
Refractive Index	n	1.7
Width of Lane		$7(m)$
Width of Vehicle		$1.8(m)$
Transmit power	P_t	$314(mW)$

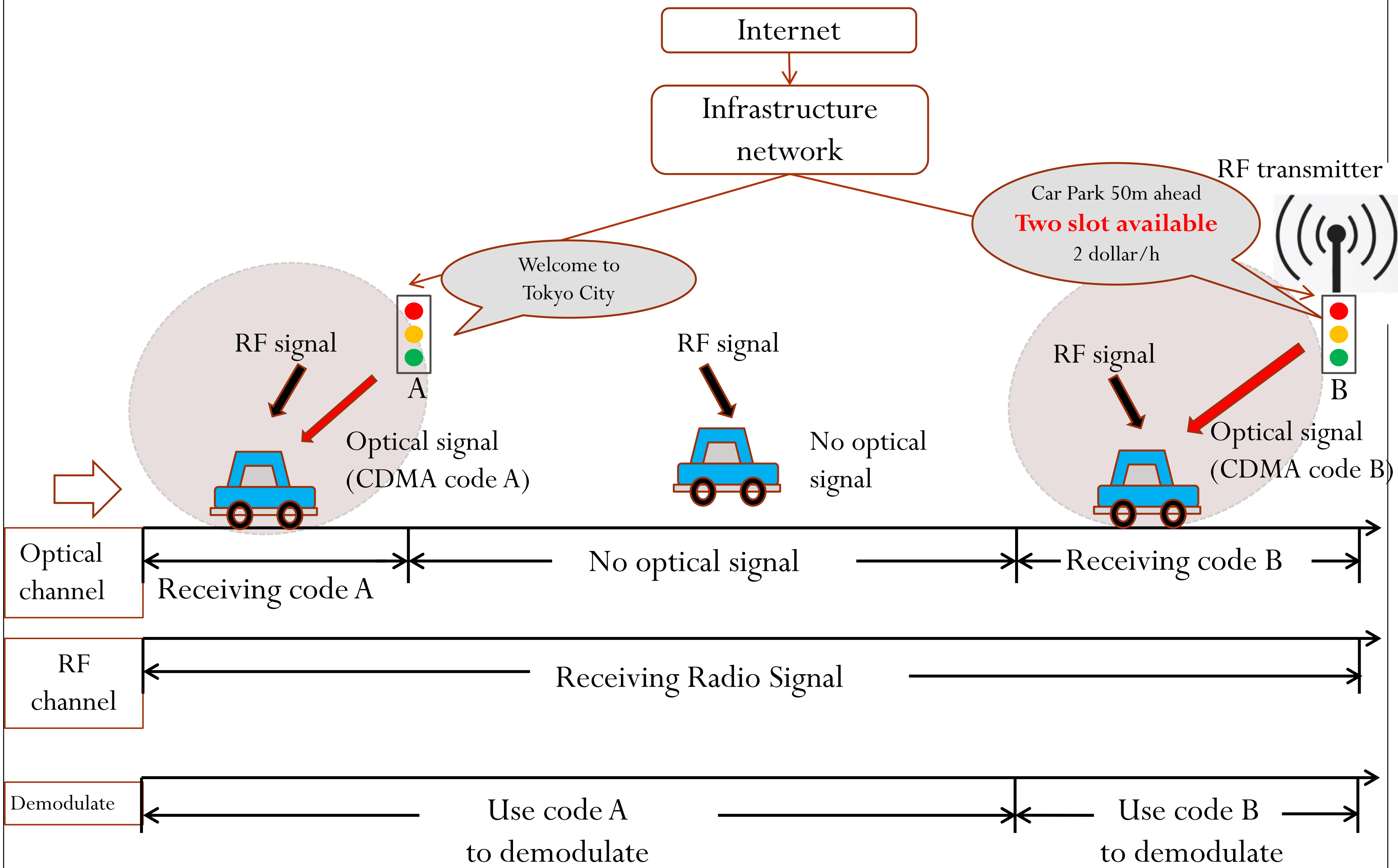


The effective coverage with different values of θ

SNR Analysis



SNR versus *x and y* ($\theta = 74^\circ$)

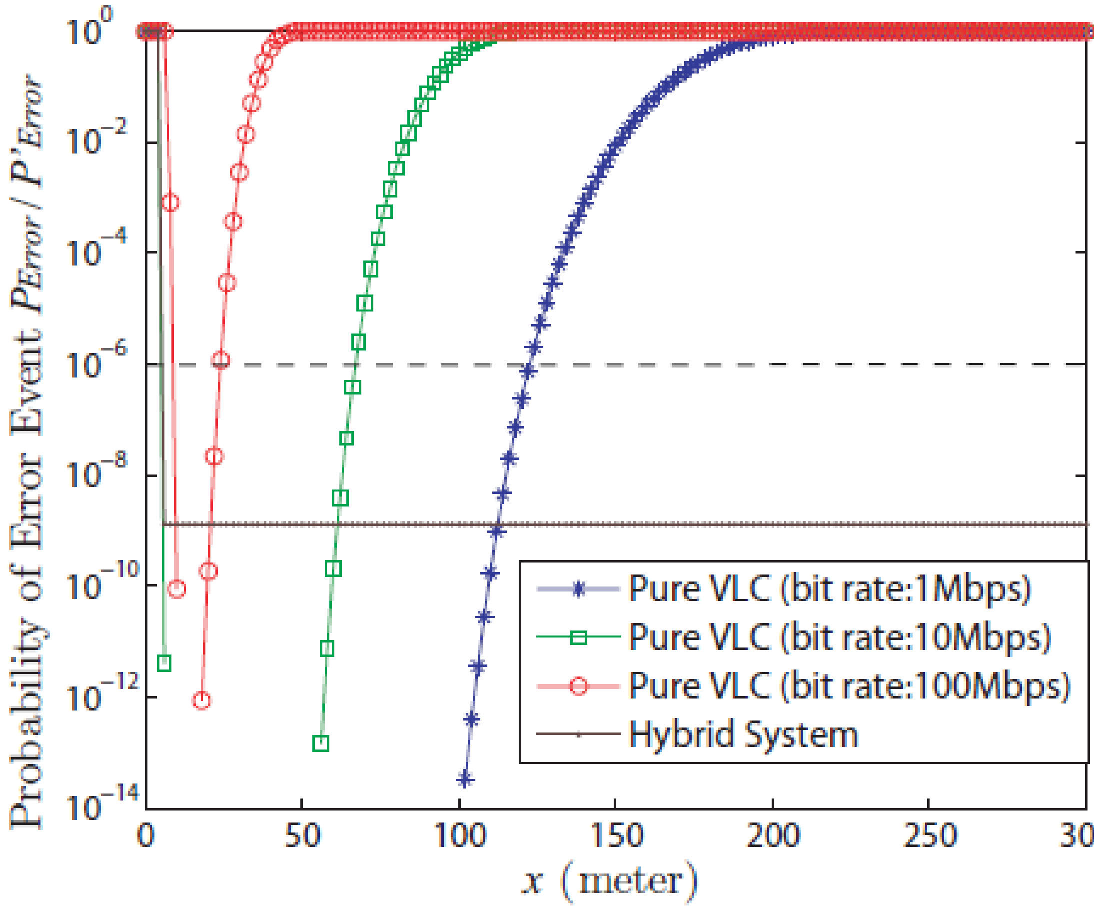


Internet
Infrastructure network
RF transmitter
Car Park 50m ahead
Two slot available
2 dollar/h
Welcome to Tokyo City
RF signal
A
Optical signal (CDMA code A)
RF signal
No optical signal
RF signal
B
Optical signal (CDMA code B)
Optical channel
Receiving code A
No optical signal
Receiving code B
RF channel
Receiving Radio Signal
Demodulate
Use code A to demodulate
Use code B to demodulate

Simulation Parameter

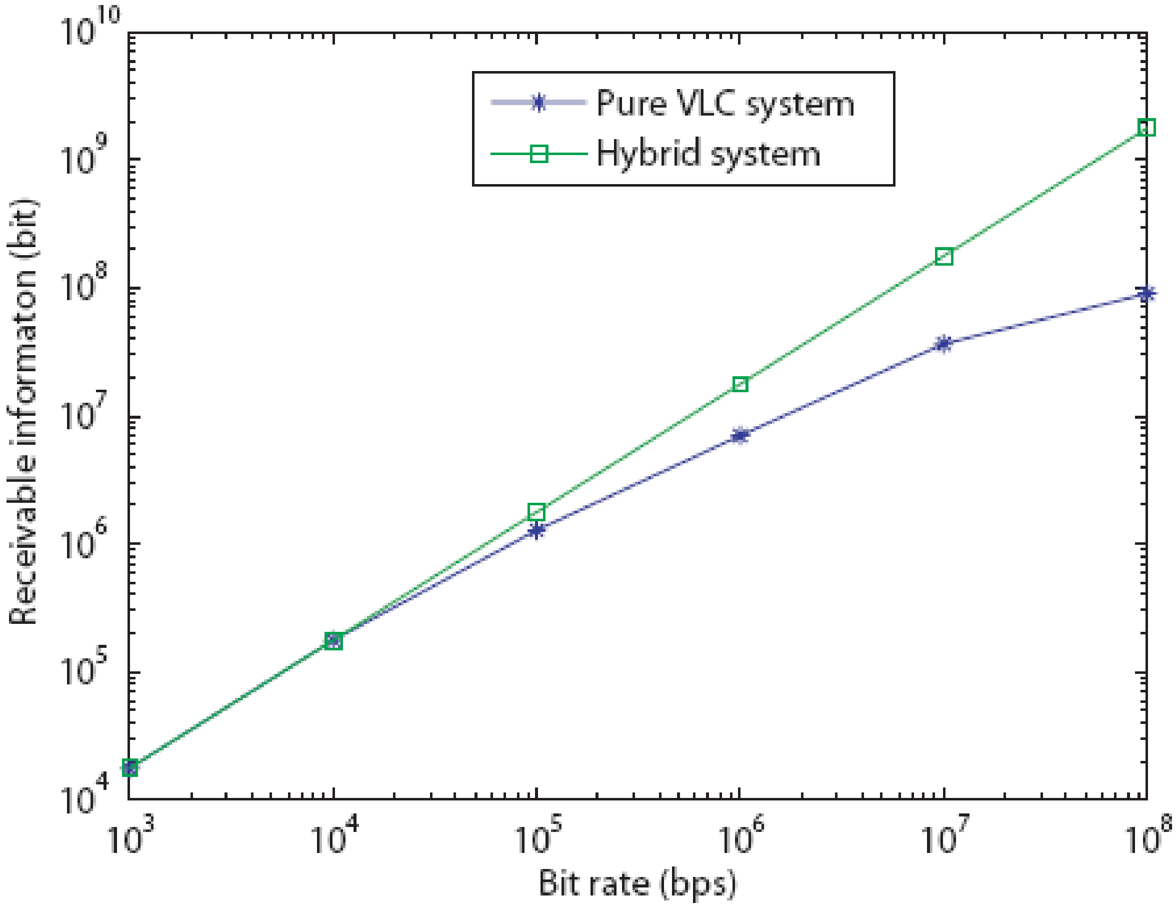
Symbol	Quantity	Value
Noise-bandwith factor	$\Delta\lambda_{nb}$	10 (nm)
Electron charge	q	$1.6 \times 10^{-19} (C)$
O/E conversion efficiency	r	0.35 (A/W)
Background irradiance per unit bandwidth	P_{bg}	$5.8(\mu W/cm^2 \cdot nm)$
Boltzmann's constant	k	$1.380662 \times 10^{-23} (J/K)$
Temperature	T_A	$300(K)$
Fixed capacitance of photodetector per unit area	η	$112(pF/cm^2)$
FET channel noise factor	Γ	1.5
FET transconductance	G_m	$30mS$
Noise bandwidth factor for white noise	I_2	0.562
Noise bandwidth factor for f_2 noise	I_3	0.868
Open-loop voltage gain	G	10

Probability of error event of the proposed hybrid system and VLC system



User number: $K = 10$, RF processing gain: $G_{RF} = 200$, the number of information bit of the ID frame : $L_{DATA} = 100$ bits, the number of information bit of the ID frame L_{ID} $= 10$ bits, $y = 0$. The bit rate of the hybrid system for optical channel and radio channel are assumed to be 100*Kbps and 100Mbps respectively.*

Receivable Information



Assume the speed of vehicle is 60 km/h, the distance between two traffic lights located in the same lane is 300 meters

Conclusion

- This paper proposed a hybrid ITS system which improves the broadcasting downlink efficiency of current traffic broadcast system.
- The proposed system offers position based communication services with high bit rate by using both visible light and radio communication system.
- It resolves the limitation of pure VLC system in coverage, while maintaining its capability of position based communication.
- Simulation results showed that the effective communication area and the receivable information can be increased by using the proposed system compared with a pure VLC system.

Thank you for your attention