Cross Strait Tri-regional Radio Science and Wireless Technology Conference (CSTRWC2005)

2005年海峡两岸三地无线科技学术会

论文集

王学田 安建平 主编

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“无线电”科学技术发展某些系统思考

北京理工大学　王　越

一、由“无线电”名词内涵延伸所关联的科学问题开放性讨论

“无线电”中文直接意义为不用导线的电磁波设备，英文 Radio 按牛津字典的解释为：利用电磁波但不用连接导线，发送或接收信息(消息)的设备，由此涉及到电磁波、信息、导线、设备四项事物，它们蕴含了开放性科学问题。

电磁波是一种物质存在形式，电磁波与其他物质相互作用科学问题的研究蕴含了众多需研究的问题，与人类社会的生存关系密切，电磁波科学本性的研究如超光速问题、电磁波对应的粒子性质延伸至量子特性(如不可约的不确定性，非局域等性的纠缠特性)都有待深入研究。

“信息”更是人类关联永恒主题之一，“信息”有关的科学研究将关联到生命科学、思维认知科学等所知甚少又很具挑战性领域，“信息”再与量子状物质相结合又形成人类期望之量子信息之基础性研究及应用基础研究。

导线作用实际上是传播电磁波之一种媒介，导线在“无线电”领域不采用，但传输的媒介还是需要的，媒介之 $\mu\varepsilon$ 之乘积为负值之媒介又称左手材料，它可能被利用形成电磁波传播很多可喜的特性，这样“无线电”领域又与材料领域相关联。

设备一词经百年的发展，已由简单低级向复杂高级发展，现在无线电设备已经发展为复杂的系统，并普遍构成由系统作为单元的体系。

二、“嵌入”特性及系统特性与“无线电”关系密切

1. 信息系统

信息系统是对荷载信息之媒介体(现在很多用电磁波及其他波)进行运作，达到以“信息”服务人类的系统。

信息系统还具有系统之共有特征，即多个子系统交织组成多层次多剖面动态系统结构，由系统结构及开放的工作状态形成系统耗散自组织功能并对外界形成特定的功能，系统并嵌入更大的系统作为子系统，有人介入系统的系统结构组成及其系统功能发挥并起重要作用的系统称为复杂开放之巨系统(钱学森先生界定)，系统处在动态运动中，系统由孕育产生，发展成长，成熟运行，以及衰退消亡所组成(虽无生命但也具有孕育产生及衰退消亡过程)

2. 信息系统之部分功能集成

信息系统由以下部分功能组成

信息获取和变换部分

信息处理部分

信息传输部分

信息控制管理部分

信息交换部分

系统接口部分

信息存储部分

一个具体信息系统的构成是根据功能要求、约束条件由上述功能部分交织(可重复)组成。而信息系统发展之瓶颈部分是信息处理(信号处理为其中部分)及信息管理控制部分，其所

涉及之科学技术众多学科尚远远不够发达，当然其他部分也具有众多挑战和期望，只不过矛盾尖锐程度现不如上述二部分而已，信息系统的不断发展和呈现的矛盾体现着信息科技和信息系统与社会共同发展进化这一规律。

3. 信息系统之极限目标

普通人在任何时间、任何地点、任何状态下都能方便地得到所需的任何信息，且越少花代价越好。

人对信息系统所规定这条目标是带有极限性质的，是永远不可能完全达到的，只可能在一定条件下接近，因为目标内容中含有本征性矛盾无法消除也就无法完成，其中“任何”等价于“绝对”，“绝对”是绝对不可能实现的，只能有相对性的接近。

4. “无线电”在信息系统之重要性体现及“嵌入”特征相应发挥

“无线电”领域之重要性就是体现以“无线”方式，它很大程度上支持了信息系统极限目标中“任何地点、任何时间、任何状态”的接近和改善，社会越是发达进步，信息系统融入社会越广泛，对信息系统的极限目标接近程度就越迫切，无线电领域的重要性将更加体现。

“无线电”之重要性日益增加，并不意味其独立完整性构成系统的加强，相反是“嵌入”性和交织相融性的加强，从系统总体角度而言，系统越复杂，系统层次必然越多，而子系统间互相交织融合程度必越加强，或称子系统间互相嵌入程度越强，“无线电”虽具有上述重要优点，但同时具有较强的约束条件，使得“无线电”往往并不能在复杂的信息系统中独立建构，而在嵌入复杂信息系统中起重要组份作用，也可嵌入已有信息系统使其升级。

但“嵌入”往往是“交织相互嵌入”！

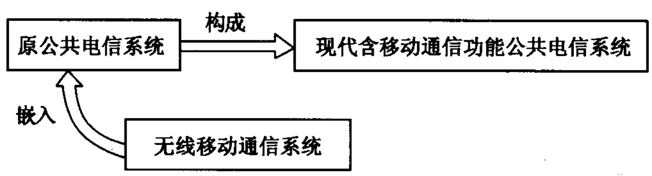

图 1　无线移动通信系统嵌入原公共电信系统构成含移动通信功能的先进公共电信系统

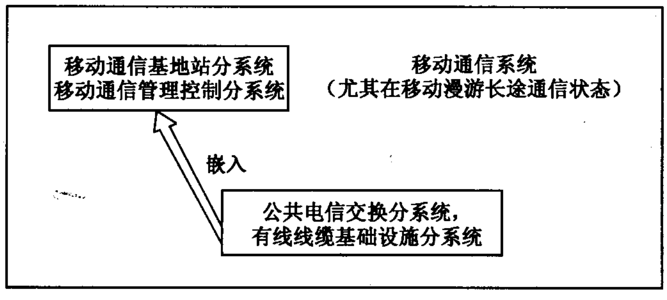

图 2　公共电信分系统嵌入移动通信分系统构成守整功能移动通信系统

其他科技之嵌入“无线电”，——从更广泛领域视角观察是相互“嵌入”。

从无线电领域角度讨论，还有多种科学技术嵌入无线电领域起增加剂或催化剂作用，它们主要有：离散数字科学技术，微电子科学与技术，控制科学与技术，材料科学与技术，系

统科学与工程。从基础科学角度尚有物理学、数学、化学、生物学等在面临新发展阶段的不断嵌入。

综上讨论，可将“嵌入”功能从系统组成角度组成以下示意图。

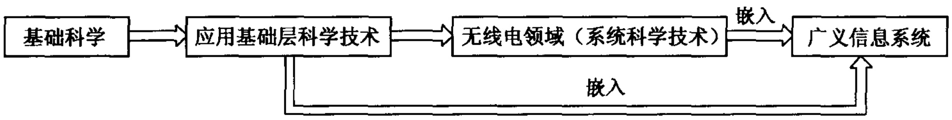

图3

三、“无线电”发展的一些思考

“无线电”的发展是一个动态的过程，上面内容已从不同角度作了些叙述，现综合性进一步讨论动态发展过程。以下列因素构成主要框架，即以社会发展人类之需求为原始推动力；以科学技术发展为基础；以“获得”与“付出”为主要权衡要素；以弱化或转移约束状态为解决发展矛盾的主要思路；以变换为主要方法；以嵌入方式构成系统再嵌入更“大”的系统中发挥作用。上述因素并非孤立单独起作用，而是相互关联相互制约，支持支持以系统性质融入发展过程。

以下我们将结合实例进行展开说明。

人类发展的需要可分为个人需要与社会整体发展需要，这两者应结合发展(如果社会整体发展中与个人或部分某类群体发生激烈矛盾时，社会必不能合谐发展)，而个人发展需要又包括个人生理(含家庭成员)需要、安全需要(含家庭成员)、融入社会生活需要、社会对个人承认需要、人精神需要(高层次需求)。

“无线电”满足个人社会需要主要是在社会生活层次以上层次发挥作用，但随着发展需求的水平越来越高复杂情况，必需依靠科学技术解决本身弱点可形成之“制约”(约束)，如在移动通信，家庭网络基础发展，集生活娱乐、理财、健康监控、工作于一体的“嵌入式强化个人数字助理(EEPDA)，必须解决个人信息、状态及使用之安全可靠问题，当然进一步减轻重量、减少耗电、降低成本也同时具有重要性。

以无线电技术形成服务百姓之人工系统研发是否成功，取决于个人使用本系统后“获得”与“付出”(代价)之比值不能低于某阀值，没有“需求”或很少“需求”者必导致没有“获得”或很少“获得”，这种情况下即使很低“付出”也很难开发成功，而“需求”和“获得”之具体内容则随社会发展和个人所在群体之特征而发展变化，超前社会发展程度很多可构成之“需要”是不现实或意义不大的“需求”，以此为依据研发新无线电系统成功概率必不高。

无线电技术嵌入式应用在各类信息中其最大之优点是其“无线”，也正是“无线”同时形成其应用中之最大弱点，即应用过程中关系方面之个性特征(含信息个性)难于保持，由此形成应用之约束条件为：只能用对个性保持要求很低的场合，很大程度上影响发挥作用，但依靠科学技术的发展可弱化上述约束条件，其基本之思路是采用科技变换的方法避开产生负面作用之可能性。

信息个性(特殊性)不能保持的类型为：

“个性信息之存在”曝露

个性信息内容曝露

个性信息所关联的对象的曝露等

信息曝露产生之后果有多种多样，这是因“信息”除本身所荷载直接信息量外，还有由信息附加义(尤其是由“信息”组成之信息作品会提供更多的附加义)所引起之后果，所有的信息后果并不由信息本身所主要包括，而主要是由额外信息获得者后续行动所造成，因此由“信

息”本身无法全部评估及预计后果，但人们总是努力采用“变换”方法及反馈方法减少无线电信息泄漏的可能性以及防止不正常后果。

对于防止个性信息内容曝露最常用的方法是采用密码加密信息内容，其原理是利用密钥所形成之对称和不对称变换(对合法通信者间是处于对称变换位置)，以对局外人进行信息内容的隐藏，对合法通信者内容是透明的，而对信息之“存在”进行隐藏可利用数字签名方法之反用，将“信息”嵌入公开信息中加以隐藏，同时还可再利用密钥对信息内容再进行一次变换加密加以保护。此外也可将无线电信号的形式加以变换类同于某些公开信息之信号形式对个性信息的存在进行隐藏，也可压缩个性信息的存在时间，在时间域空间域进行联合隐藏，但所有进行上述减弱无线电技术在应用中约束限制的变换，其基础是科技的进步和发展，科研发展是无止境的，但人类的需求和产生之矛盾也无止境，由此形成了发展矛盾无止境的动态运动发展，最近随着生物科技的进展将红膜检测技术用于个性的精确认定以减弱个性信息曝露所引起的后果，便是一例，但实现需要一系列科学技术前沿成果加以支持。

将以上讨论可以浓缩为下列框图示意表示。

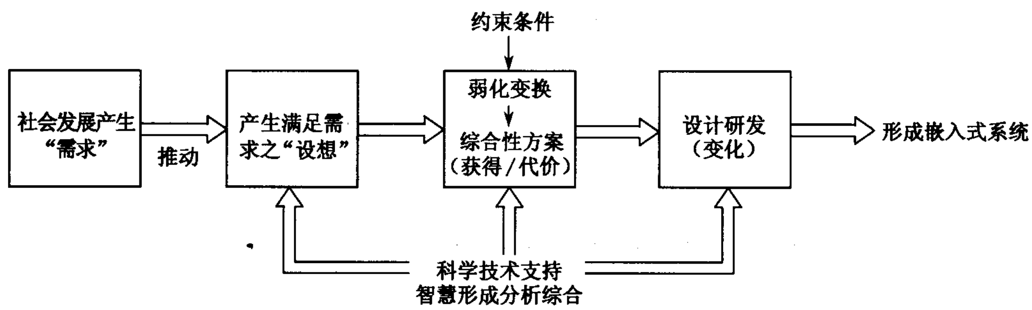

图 4

Development and Test of Mobile Ad-Hoc Routing Protocols

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Abstract: This paper presents a comparative study between min-hop-based and stability-based ad-hoc routing protocols for mobile ad-hoc networks. The both routine protocols are developed based on IEEE 802.11 technology and system operating in an ad-hoc mode. The measurement result shows that the system with stability-based routing protocol provides sufficient data throughputs for mobile video service as well as higher stability. The system using the min-hop routing protocol may exhibit higher throughputs but provides lower performance stability. The stability-based routing protocol seems to be applicable for various vehicular communication services.

Keywords: Mobile ad-hoc network ad-hoc routing protocol IEEE 802.11

I. Introduction

The popularity of wireless communication systems can be seen almost everywhere in the form of cellular networks, WLANs, and WPANs. In addition, small portable and mobile devices have been increasingly equipped with multiple communication interfaces together with mobile ad-hoc networking capability to build a heterogeneous environment in terms of access technologies. The desired ubiquitous computing environment of the future has to exploit this multitude of connectivity alternatives resulting from diverse wireless communication systems and different access technologies to provide useful services with guaranteed quality to users. Recently, interest in Mobile Ad-hoc NETwork (MANET), which is one of the most important techniques for ubiquitous computing, has increased due to its ability to enable the network to be easily deployed and allow all nodes with wireless interfaces to move around freely [1]. Mobile ad hoc networks mean wireless multi-hop networks formed by a set of mobile nodes without relying on a preexisting infrastructure. MANET applications have mainly been for military applications or emergency situations. However, research into MANET routing protocols will lay the groundwork for future wireless sensor networks and wireless plug-n-play network devices.

MANET routing protocols play a fundamental role in a possible future of ubiquitous devices. Due to the nature of time-varying network topologies and shadowing effect of neighboring obstacles (moving vehicles) to the mobile, its routing protocol needs to overcome the problem cause by unstable radio links. Traditional ad hoc routing protocols, which are generally regarded as *min-hop-based routing protocols*, are purely designed to react the network topology changes. Several well-known min-hop-based routing protocols are available in the literature [2], including Destination Sequenced Distance Vector, Optimized Link State Routing Protocol, Ad Hoc on Demand Distance Vector Routing (AODV) [3], and Dynamic Source Routing.

Although min-hop routing protocols such as AODV are claimed to provide high throughputs due to the throughputs of multi-hop route are decreased with the increasing of number of hop counts. However, the temporal and spatial varying characteristics of radio communications are not considered into min-hop routing protocols. *Stability-based routing protocols*, which might adapt to radio propagation effects, time-varying signal strengths, and moving speeds of mobile nodes, are required to overcome the temporal and spatial varying radio links. Several ad hoc routing protocols adapted to link or route stability are proposed, including Associativity Based Routing [4] and Signal Stability-based Adaptive Routing [5].

Most of previous works on MANET performance evaluation are proceeded by computer simulations. Our work is prompted by the lack of published results concerning the issues associated with the performance of MANET platforms in vehicular environments. This paper presents our work on development and performance evaluation of MANET systems in order to check and compare the performance of min-hop-based and stability-based ad hoc routing protocols. The AODV routing protocol is selected and implemented [6] in our PC-based measurement system to obtain the performance of min-hop-based routing protocol. On the other hand, a commercial prototype of Opportunity Driven Multiple Access (ODMA) [7] MANET facility is regarded as the stability-based routing protocol in our field measurement. Both implementations of MANET routing protocols are executing with underlying physical layer and MAC layer protocols inherited from wireless LAN (IEEE 802.11b).

Section II presents the development details of our MANET platforms followed by the measurement scenarios descriptions in Section III. Section IV provides measurement results and analysis of our field test. By examining the measurement results, further comments on MANET technologies for vehicular applications are provided. Some of our current works on developing novel stability-based routing protocols modified from AODV are also presented in Section V. This paper is concluded in Section VI.

II. Development of Manet

Two types of MANET platforms are developed and examined in this research, including the PC-based MANET measurement system with AODV routing protocols and the ARM-based ODMA embedded MANET node. The details of these platforms are presented as follows:

A. The PC-based MANET measurement system

The system diagram and physical picture of a single node of the MANET system is shown in Figure 1. This system is adapted from IBM PC-based computers. As depicted in Figure 1, both IEEE 802.11b WLAN card and GPS module are integrated in the MANET system. As a result, the measured data throughput and geographic locations can be recorded and stored in the computer simultaneously.

As to the software environment, the Linux-based operating system is adopted with necessary benchmarking tools and drivers. Based on the Linux operating system, three modules are developed in the MANET system: traffic generator, GPS message parser, and the AODV routine protocol. Traffic generator module and GPS message parser are integrated as a measurement program to save the received data packet versus the vehicle position.

B. The ODMA MANET node

IWICS Inc. has successful developed the commercial prototype of ODMA-based MANET node. This system is an ARM-based embedded platform, which integrates IEEE 802.11b wireless adaptor and the software module of ODMA routing protocol. IWICS Inc. claims that the wireless adapter of the ODMA prototype would be upgraded to an OFDM-based adapter (i.e., 802.11a, 802.11g) to obtain better throughputs in near future. High gain antenna is also available in this system for outdoor applications. As to the

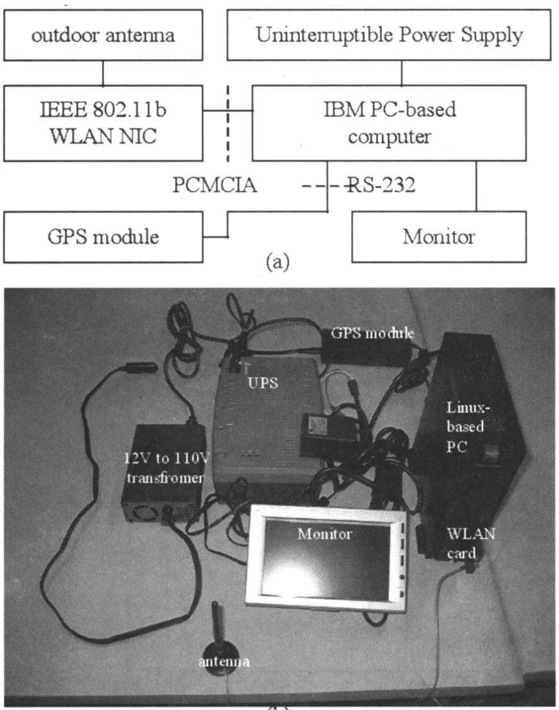


Figure 1 Single node of the MANET measurement system: (a) The system block diagram; and (b) Picture of the system.

software environment, the NAT and DHCP services are enabled to perform packet forwarding for the RJ45-connected facilities. Therefore our developed PC-based measurement system is able to connect to the ODMA MANET node and measure the system performance.

III. Measurement Scenarios

Measurements are conducted for varied communication models under different propagation environment and vehicular mobility scenarios. The measured data throughputs are sampled for every second. Major experiment scenarios are depicted as following paragraphs:

A. Single-hop communications

In the single-hop transmission test that is regarded as the baseline measurement, the performance of 1-hop ad-hoc communication has been tested using the PC-based MANET measurement system. This measurement is made on the freeway. The freeway is an open area with scarce roadside vegetation and buildings. Moving cars traveling among test vehicles may cause obstruction direct waves and leads to shadow fading. The measurement is carried out in freeway 68 of Taiwan. The data throughputs are obtained among different relative velocities between two cars and TCP and UDP protocols are both deployed in this test.

B. Mobile-to-fixed multi-hop communications

The measurement is carried out in sub-urban. Few buildings and tree plantations are spread around the roadside. Excepting the receiving vehicle, the transmitting and intermediate nodes are fixed at roadside in this test. The throughput variation is obtained between the communication service from fixed transmitting node and the moving receiving car. The GPS position of each measured record is also logged for further analysis. For the AODV MANET system, the measurement is made in National Chiao-Tung

University campus. Total 3 fixed nodes, including the transmitter node, are sited along the road. On the other hand, for the ODMA MANET node, the measurement is made in a medium scale MANET testbed, which contains more than 30 fixed nodes in a 1.2km*1.2km area in LongTan, Taiwan. The ODMA testbed is situated in the practical urban environment. Average heights of buildings along the streets are about 15-20 meters.

C. Mobile-to-mobile multi-hop communications

The vehicle moves along city streets in HsinChu has speed limits of 40 kilometers per hour. Average heights of buildings along the streets are about 15-20 meters. The measurement is done in the rush hour with traffic jams and vehicles often stopping at traffic lights. Four test vehicles are moving freely in a restricted geographic region. The data throughput is measured from the data transmission between selected two vehicles. Because it is difficult to control the driving velocity and interval distance between test cars, we analyze the logged snapshot and make some comments.

Ⅳ. Measurement Results and Analysis

The results obtained from the experimentation are presented herewith. Wireless LAN performance for the ad-hoc communication between two vehicles is noted by observing the throughput with variation in relative driving speeds in freeway environment. Multi-hop communications performance are examined by snapshots and average throughputs in sub-urban environment.

A. Single-hop communications

Figures 2 and 3 present the data throughput in TCP and UDP transport modes, respectively. Different relative speeds between the vehicles are

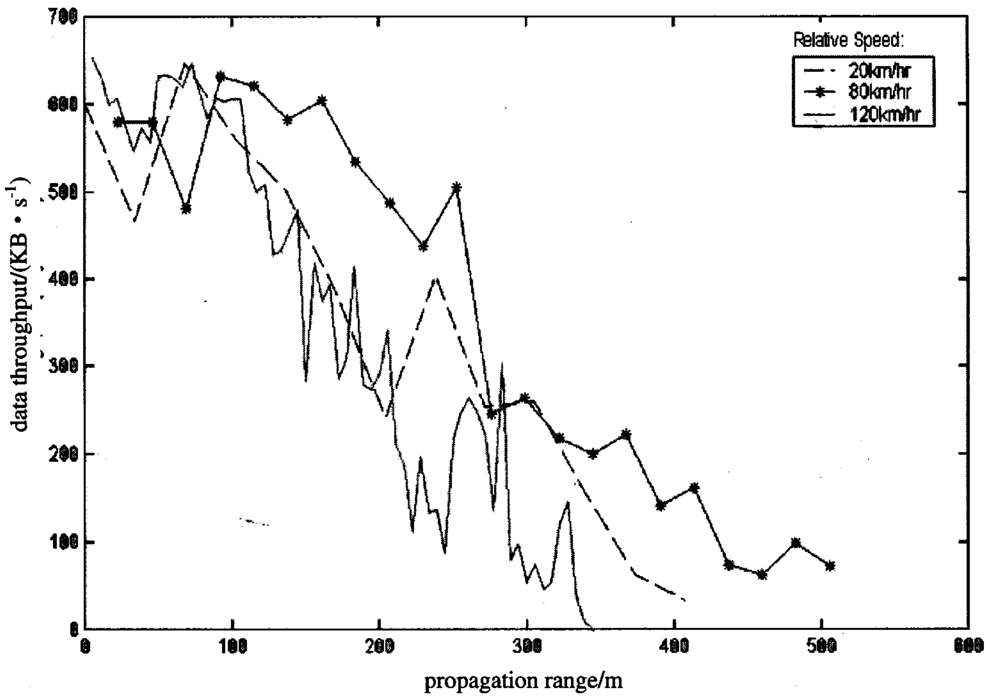


Figure 2 Data throughput in TCP transport mode v.s. propagation distance for different relative speeds between vehicles

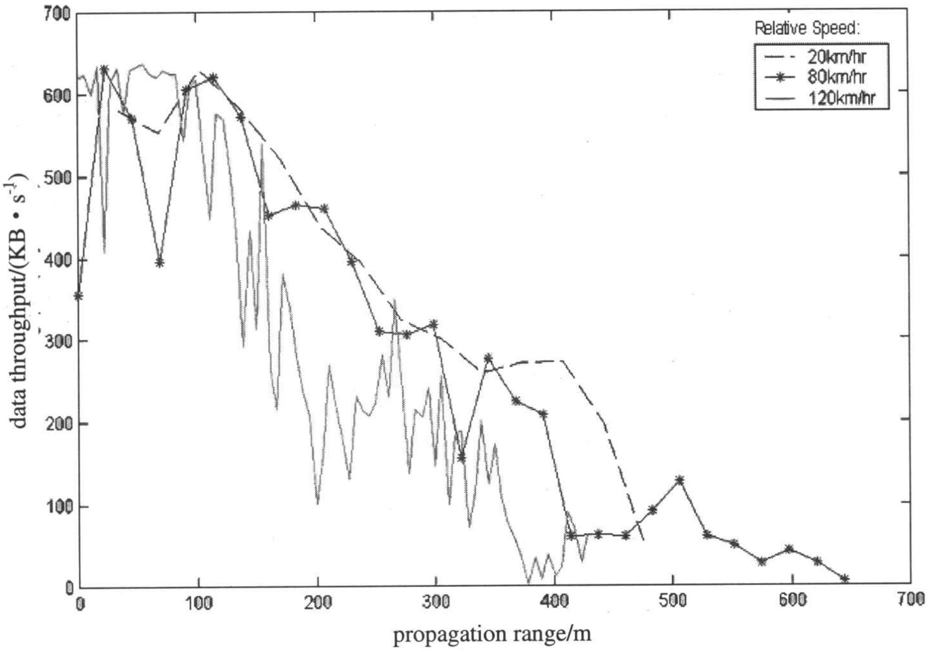
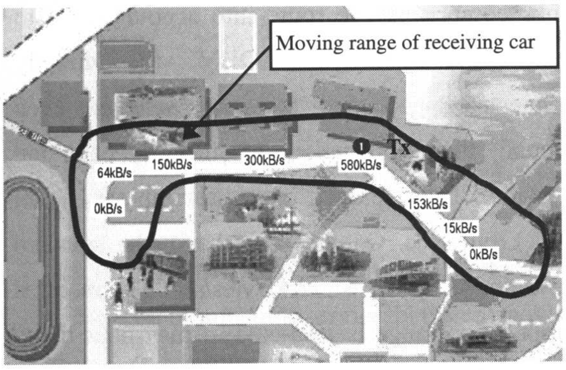
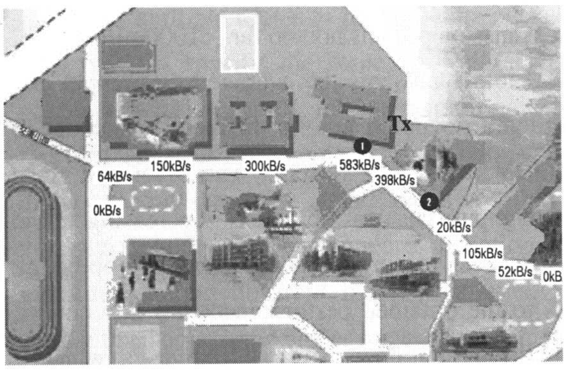


Figure 3 Data throughput in UDP transport mode v.s. propagation distance for different relative speeds between vehicles



(a)



(b)

Figure 4 Mobile-to-fixed communications in AODV: Throughput variations in sub-urban scenarios, (a) 1-hop transmission and, (b) 2-hop transmission

considered. The both figures show that the data throughput is decreased as the distance increases, which is mainly due to the decrease of the signal strength. It is also found that the throughput could reach up a good performance at 100m to 200m propagation distances. The measured results also shows that the higher the relative speed, the larger the deviation of data throughputs. The fast fading effects obviously influence the propagation channel in high relative speed. In comparison among transport protocols, the variations in TCP mode are more mitigative than the ones in UDP mode. However, the connectivity ranges in UDP mode are longer than the ones in TCP mode.

B. Mobile-to-fixed multi-hop comm unica-tions

1) *AODV MANET System*: Figure 4 plots the locations and measured throughputs of the mobile-to-fixed communication of AODV MANET system in the campus. As depicted in Figure 4(a), the receiving car is moving in the circled region. The transmitting node is sited at the position denoted by "1", and measured

throughput decreased with the increased distance between transmitter and receiver.

In the multi-hop experiment, a new intermediate node denoted by "2" is sited as depicted in Figure 4(b). It obviously indicates that the connectivity range is increased by the new node. It is worth to notice that the obtained throughput closer to the right side of position "2" is 20 kBytes/sec, which is much lower than farer locations logged as 105 kBytes/sec and 52 kBytes/sec. This phenomenon shows that AODV protocol could not discover high-performance transmission route due to the directly connected poor link is selected which provide worse performance.

2) *ODMA MANET System*: In this test, the mobile node is moving freely in LongTen ODMA testbed and transmits packets to the fixed receiver in order to obtain throughputs. Figure 5 plots data throughput vs. distance between moving transmitter and fixed receiver in our testbed. By examining measurement results, the obtained throughputs decrease with the increasing of distance. It is cause by the increasing of average hop count of transmitting paths. The longer the distance between transmitter and receiver, the larger the average hop count.

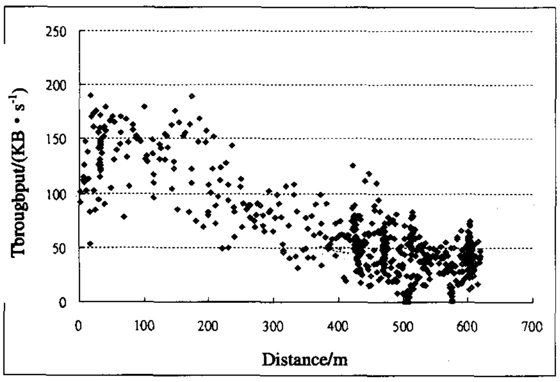


Figure 5 Mobile-to-fixed communications in ODMA: Data throughput vs. distance.

On the other hand, the standard deviation in this test is about 40kBytes/sec. Although the average data throughput is less than our AODV MANET system, it performs more stable than the AODV implementation. The proposed ODMA MANET system still provides satisfactory stability for common application like mobile Internet and data exchange in ITS.

C. Mobile-to-mobile multi-hop communications

1) *AODV MANET System*: Figure 6 presents a portion of total snapshots in our test. By examining Figure 6, the vibration range of throughput variation could be from 0 to more than 600 kBytes/sec. The variation of throughput suddenly increased when the connecting route is broken and recovering. This phenomenon indicates that poor performance is mainly due to the creation and maintenance of routes without taking the stability, or quality, of the network links comprising the route into account. Due to the characteristic of AODV, the directly connected 1-hop route is mostly selected, even though the propagation channel is bad and unstable. The averaged data throughput is about 400 kBytes/sec. On the other hand, the standard deviation is up to 147.72 kBytes/sec. The required propagation range is restricted in rush hour urban traffic so that inter-vehicle communication service can be reached when the distance between transmission peers is not too far (<1000m).

Table 1 presents the averaged throughput and standard deviation among different hop count in AODV MANET system. The averaged data throughput has an obviously decreasing trend with the increasing of total number of hop count. As to the obtained performance in 3 hop counts, the throughput decreases to 170kbytes/s, which is about only 30% throughput obtained in 1 hop transmission. The obtained standard deviations are quite large, which indicates the low stability of the multi-hop transmission quality. This phenomenon indicates that the number of hop counts seriously suffers the performance of AODV routing protocol.

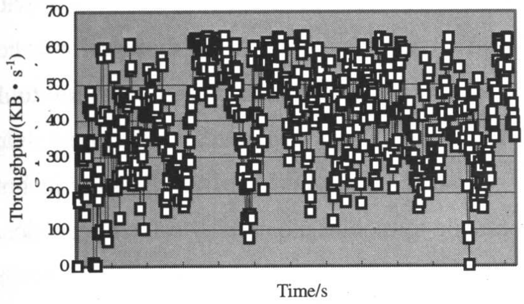


Figure 6 Mobile-to-mobile communications in AODV: throughput snapshots in urban environment

Table 1 Mobile-to-mobile communications in AODV: Throughputs and standard deviations for different hop counts

Total no. of hop count	Throughput (kBytes/s)	Standard Deviation (kBytes/s)
1	593.07	102.35
2	386.74	108.2
3	170.19	44.05

2) *ODMA MANET System*: In this test, the wireless communication service between moving vehicles is provided by multi-hop routes organized by moving vehicles. Because ODMA maintains multiple routes to forward data packets, it is hard to specify the route as well as hop counts of a given source and destination pair. So this test is focus on average throughputs under heterogeneous scenarios. As presented in Table 2, data throughputs and its standard deviation are measured among different moving patterns. By examining Table 2, the closer the moving vehicles, the higher the data throughputs could be obtained. As a stability-based routing protocol, when all cars circling a building, multi-hop paths can easily make a detour to avoid directly blocks of propagation channels. Satisfactory performance as 90.03kBytes/sec is obtained in the circling scenario.

Table 2 Mobile-to-mobile communications in ODMA: Throughputs and standard deviations (all nodes are moving)

Moving Patterns		Throughput (kBytes/sec)	Standard Deviation (kB/s)
space between cars	obstacles		
5~20m	lightly	117.7	28.49
20~50m	lightly	80.84	34.51
5~20m	heavily	90.03	56.6

In order to investigate the performance of mobile-to-mobile communication while provisioned fixed nodes are existed around mobile nodes, an additional mobile-to-mobile measurement is made in the LongTan ODMA testbed which contains preexisted fixed MANET nodes. Four moving patterns related to moving vehicles carrying with ODMA MANET nodes are tested. Comparing to prior scenario, the objective of this test is to verify if the provisioned fixed nodes can improve the performance of mobile-to-mobile communication in MANET or not. As presented in Table 3, data throughputs and its standard deviation are measured among different moving patterns.

Table 3 Mobile-to-mobile communications in ODMA: Throughputs and standard deviations (only transmitter and receiver are moving)

Moving Patterns		Throughput (kB/s)	Standard Deviation (kB/s)
space between cars	relative speeds		
5~20m	0~10km/hr	174.07	18.69
20~50m	0~10km/hr	95.93	20.18
0~1000m	40~100km/hr	52.05	40.07
1000~1500m	0~100km/hr	18.54	8.53