行政院國家科學委員會專題研究計畫 成果報告

結合感測網路及無線接取網路之車用行動隨意網路技術與系統研究

研究成果報告(精簡版)

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一、報告內容：

With the advance of technology in miniaturizing and integrating onboard electronic devices, vehicular networks that allow vehicle-to-vehicle and vehicle-to-infrastructure communication have gained momentum and attracted a lot of attention recently. Vehicular ad hoc networks (VANETs) can be considered as one subclass of mobile ad hoc networks (MANETs) where nodes move by following the road infrastructure and traffic regulation. It is due to the similarity between VANETs and MANETs that many issues arising in vehicular networks can be or have been addressed by the wealth of research endeavors in conventional mobile ad hoc networking. For example, many medium access control, channel assignment, broadcast, and multi-hop routing protocols proposed for general mobile ad hoc networks have found their applications in vehicular ad hoc networks.

Since a vehicular ad hoc network is a special type of mobile ad hoc networks, there exist several dimensions where MANET network protocols can be optimized for better performance in the vehicular environment. For example, although mobility of individual vehicles may seem arbitrary, it is somewhat "predictable" in the sense that vehicle movement is constrained by road infrastructure and vehicles typically move by following the road signs such as speed limit and traffic lights. Such characteristics of the vehicular ad hoc networks thus can potentially be leveraged for improving the performance of network protocols.

In this project, we investigate the benefits of using vehicular context information such as GPS location, vehicle speed, street map, and/or traffic condition to improve the performance of routing protocols in urban vehicular ad hoc networks. We note that related work has already proposed several VANET routing protocols that take the special mobility pattern of vehicles into consideration, including GVGrid [2], MURU [3], MORA [4], PGB [5], and PBR [6]. Some of these approaches, however, use only the distance information for route selection [5], while some approaches consider only the highway scenarios [4][6]. Some approaches do consider urban scenarios, but they either rely on probabilistic models to predict the probability of making turns and/or being stopped at intersections [2][3], or assume knowledge of the driving plan of individual vehicles [3] for optimizing route selection. Such assumptions limit the applicability of these approaches in practical vehicular ad hoc networks.

Similar to related work, we assume that each vehicle is equipped with a GPS receiver and a street map. We also assume that vehicle is aware of its driving speed through the onboard velocity sensor. Unlike related work, however, we do not assume that the location of the destination to be known at the source *a priori*, and we do not make assumptions on the driving plans of individual vehicles and the probability of making turns or being stopped at intersections. Our goal is to show that the performance of conventional "VANET-agnostic" routing protocols can be significantly improved through appropriate extension of its protocol operation to handle vehicular context information.

To proceed, we consider a Manhattan grid topology and setup the simulation environment using a microscopic traffic simulator [7] and a packet-level network simulator [8]. The grid topology covers an area of 2km x 2km as shown in Figure 1. One building located at (800, 1000) of the topology acts as the gateway node, and individual vehicles generate requests to download (or upload) data (e.g. multimedia clips) from the gateway node. The ad hoc on-demand distance vector (AODV) routing protocol [9] is used as the routing protocol for data delivery between the source and destination nodes.

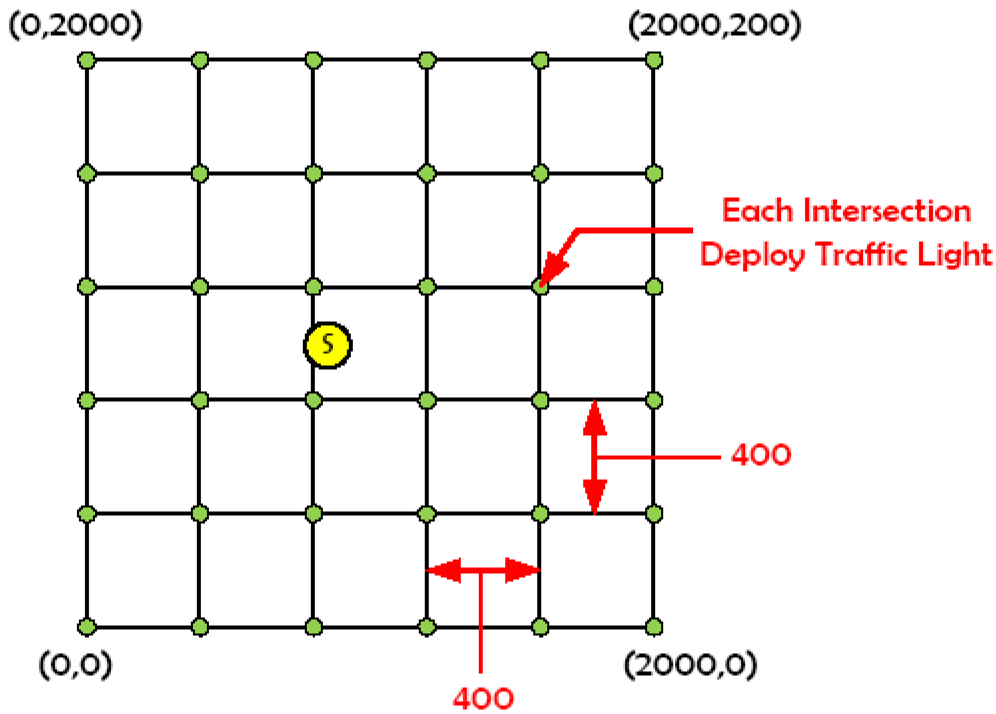

Figure 1: Manhattan Grid Topology

We conduct simulations for a network of 300 vehicles with random driving plans. We vary the number of lanes and the number of concurrent data flows for different simulation runs. Simulation results show that AODV does not perform well in the target environment with low packet delivery ratio. To understand the reasons that cause packet drops, we classify dropped packets into 4 types as shown in Figure 2. It can be observed from the figure that while node mobility accounts for about 60% of packet drops due to poor route selection, a substantial portion of packet drops is due to congestion of the wireless channel. In particular, about 20% of packets are dropped at the source before their initial routes are constructed due to repeated collisions of the route request packets with periodic HELLO packets.

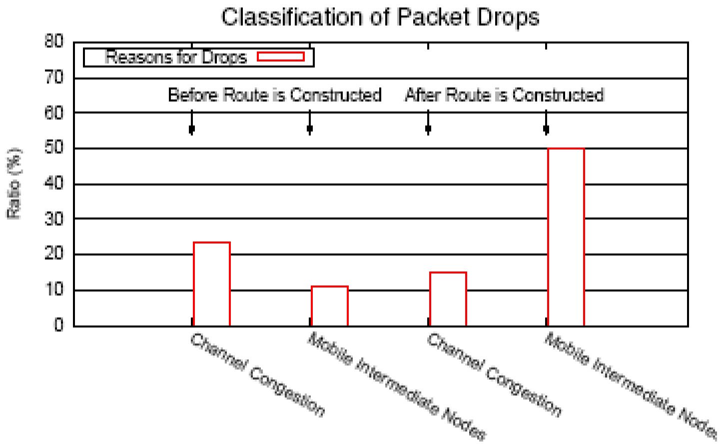

Figure 2: Classification of Packet Drops in AODV

To improve the performance of AODV in the target environment, therefore, both the problems due to node mobility and channel congestion need to be addressed. We thus propose mechanisms to be incorporated in AODV to leverage vehicular context information for minimizing the number of dropped packets. Specifically, each node puts its GPS location (x_i, y_i), moving speed (V_i) and direction (ϕ_i) in the HELLO packet it sends out. The lifetime τ of the link between two nodes located at (x_1, y_1) and (x_2, y_2) with transmission range R thus can be calculated by referring to Figure 3 as: $\tau = \dfrac{-B+\sqrt{B^2-4AC}}{2A}$, where

$A = V_1^2 - 2V_1V_2\cos\theta + V_2^2$, $B = 2dV_2\cos\theta\cos\phi - 2dV_1\cos\phi + 2dV_2\sin\phi\sin\theta$, $C = d^2 - R^2$, and

$d = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2}$, $\phi = \tan^{-1}\dfrac{y_2-y_1}{x_2-x_1} - \phi_1$, $\theta = \phi_2 - \phi_1$.

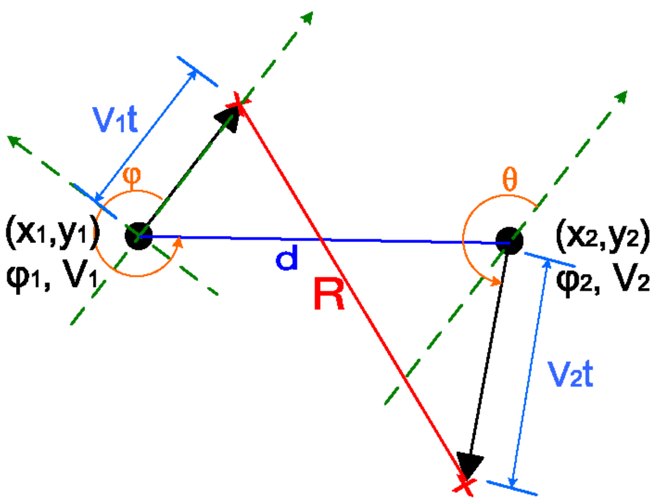

Figure 3: Prediction of the Link Lifetime

The routing process of AODV thus can be augmented with the lifetime prediction model in the following three phases:

1. Route Discovery Phase—*Prioritized RREQ Forwarding*: When a node receives the route request (RREQ) packet, it uses the information contained in the packet to calculate the expected lifetime of the concerned link. The node then defers rebroadcasting of the RREQ packet for an amount of time inversely proportional to the link lifetime. This mechanism prioritizes link with longer lifetime and avoids repeated collisions during RREQ rebroadcasting. (As nodes turn or slow down, the expected link lifetime is recalculated as mentioned later.)

2. Route Maintenance Phase—*Opportunistic Broadcast of HELLO Packets*: Unlike in AODV where the HELLO packet is broadcast periodically, in the proposed mechanism the HELLO packet is transmitted adaptively depending on the degree of change in vehicle direction and speed. A change in the direction after crossing an intersection thus can be captured by the HELLO packet. This mechanism reduces the control overheads for sending HELLO packets.

3. Route Recovery Phase—*Proactive Route Probing*: Whenever a node receives the HELLO packet from its neighbors, it recalculates the expected link lifetime using the updated location, speed, and direction of movement. If it is found that the link is to fail within a threshold amount of time, the node proactively issues a route error (RERR) packet to initiate a new route. This mechanism minimizes the number of packet drops due to route failures.

We implement the proposed mechanisms in AODV and compare its performance against vanilla AODV. Figure 4 shows the performance improvement of the proposed routing protocol in the grid topology.

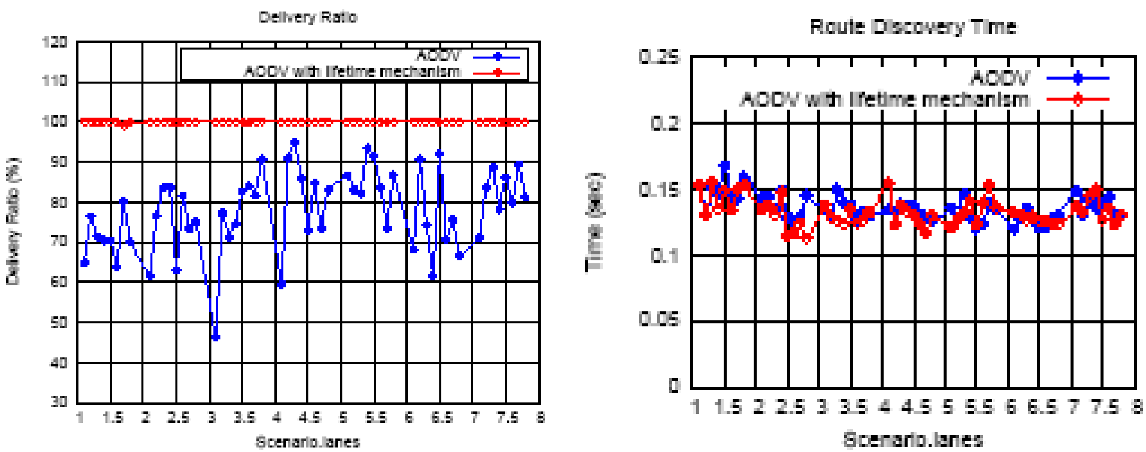

Figure 4: Performance of the Proposed Routing Protocol (AODV with Lifetime Mechanism)

We vary the number of lanes on each road in the grid topology, and hence the x-axis labeled as *a.b* in Figure 4 indicates simulation scenario *a* with *b* lanes on each road. For a total of 56 different simulation scenarios, it can be observed from Figure 4 that the proposed mechanism does perform better than vanilla AODV both in terms of packet delivery ratio and route discovery time. The reason, after careful analysis with packet drop reasons, is due to the decrease in the number of broken links during simulation. The lifetime prediction model thus can help AODV discover routes with longer lifetime and minimize the occurrences of link failures. Note that while we prioritize RREQ forwarding during the route discovery phase, the increase in route discovery time is minimal. Rather, in some scenarios it can be observed that the route discovery time in the proposed protocol is even lower than that in vanilla AODV due to the reduction of time spent for channel contention.

Figure 5 compares the overhead of route control packets in the proposed routing protocol and vanilla AODV. Route control packets include RREQ, RREP, RERR, and HELLO packets. As can be observed in Figure 5, the number of HELLO packets is significantly reduced in the proposed routing protocol due to the opportunistic broadcast mechanism of HELLO packets. Also, the number of RREQ packets in the proposed routing protocol is reduced due to the decrease in the number of broken routes and hence the requirement for frequent route requests. Therefore, from Figure 4 and Figure 5 we conclude that the proposed routing mechanism (AODV with lifetime mechanism) performs better than vanilla AODV in vehicular ad hoc networks.

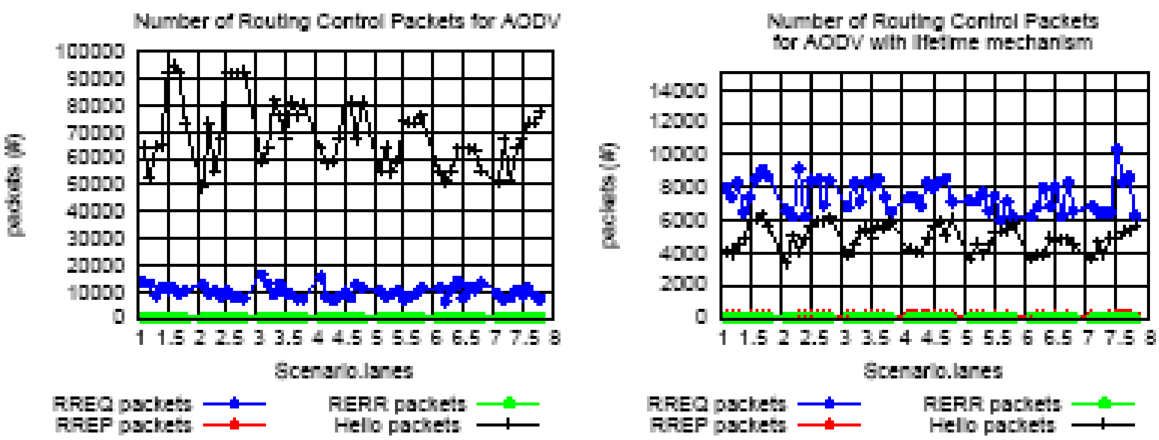

Figure 5: Comparison of Route Control Overhead

In addition to the Manhattan grid topology shown in Figure 1, we also evaluate the performance of the proposed routing protocol using a realistic city topology as shown in Figure 6. The street map is based on a central region of the Taipei city and it covers an area of 2.8km x 2.2km. The road infrastructure including the orientation, number of lanes (the number next to each line segment in the figure), speed limit and the duration of traffic lights at each intersection roughly follow that in the real world. The city topology along with the desired density of vehicles is then used as the input to the traffic simulator to generate vehicle traffic flows. The gateway node where each node communicates with for Internet access is located at (1680, 920) as shown in the figure.

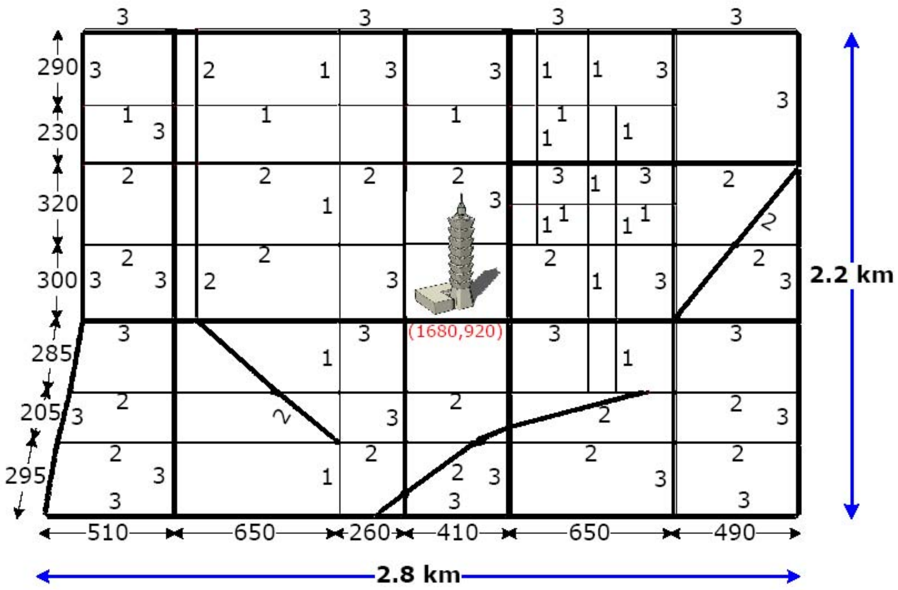

Figure 6: City Topology

Figure 7 compares the performance of the proposed routing protocol with vanilla AODV in terms of packet delivery ratio and end-to-end latency when the transmission range of individual nodes is varied from 200m to 700m. It can be observed from Figure 7 that for all transmission ranges, the proposed routing protocol performs much better than vanilla AODV owing to the *link lifetime prediction model* and the three mechanisms that we introduce for optimizing the routing protocol to vehicular ad hoc networks: *prioritized RREQ forwarding in consideration of the link lifetime, opportunistic broadcast of HELLO packets in consideration of the node mobility, and proactive route probing in consideration of the dynamic topology changes in the vehicular ad hoc network environment*.

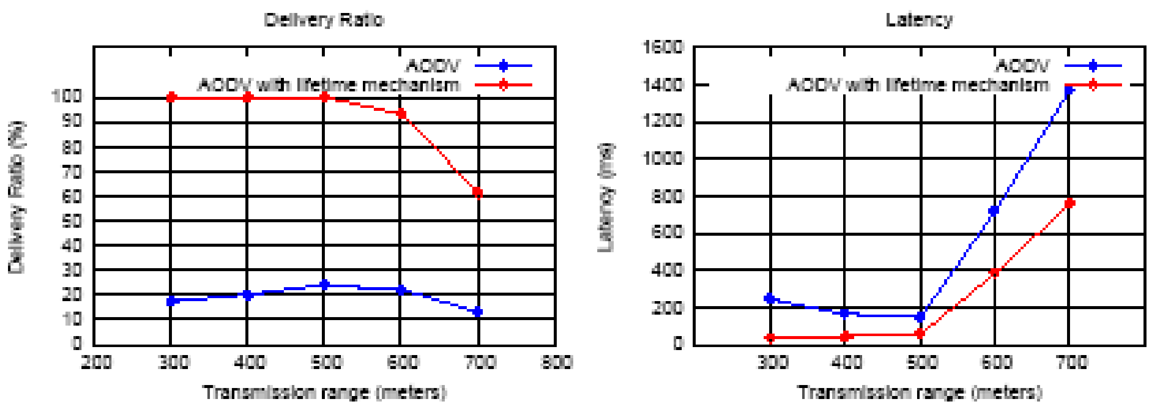

Figure 7: Performance in the City Topology

二、參考文獻：

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三、計畫成果自評：

This project proposes to investigate the networking problems in building intelligent transportation systems through incorporation of three enabling networking technologies including vehicular ad hoc networking, sensor networking, and wireless access networking in three stages. In the first stage (*for which this report is written*), we focus on vehicle-to-vehicle and vehicle-to-roadside communications, and consider the urban vehicular ad hoc networks thus formed. We have shown in this report why existing MANET protocols such as AODV fail to provide the desired solutions for the target environment, and then proposed a routing protocol optimized to the characteristics of VANETs including rapid topology changes and mobility constraints. Evaluation results show the benefits of the proposed routing protocol for the target environment. Part of the research achievement has been published in the MS thesis and under submission for conference and journal papers. We believe that the execution of this project in the first year has laid the foundation for follow-up research in the following stages for integration of wireless sensor and access networking technologies.

出席國際學術會議心得報告

計畫編號	NSC 95-2221-E-002-090-
計畫名稱	結合感測網路及無線接取網路之車用行動隨意網路技術與系統研究
出國人員姓名 服務機關及職稱	國立台灣大學電信所 謝宏昀助理教授
會議時間地點	September 26, 2006 – September 28, 2006 in Los Angeles, CA, USA
會議名稱	ACM International Conference on Mobile Computing and Networking (MobiCom)
發表論文題目	N/A

一、參加會議經過

The ACM International Conference on Mobile Computing and Networking (MobiCom) is one of the most prestigious conferences in the mobile computing and wireless networking research community. Many significant research breakthroughs in wireless networking have been published in this conference. This year, MobiCom accepts 35 papers with an acceptance rate of 11.7%, but as usual it still attracts a lot of attendees from academia and industry all over the world to Marina del Rey in California, USA.

The MobiCom main conference (excluding tutorials and workshops) is single track that schedules the technical program in three days. The first day includes a keynote speech from Dr. Andrew Viterbi on "Mobile Broadband Evolution: From Controversy to Convergence," an Athena Award lecture from Prof. Deborah Estrin on "Wireless Sensing Systems: From Ecosystems to Human Systems," two technical paper sessions on "Mesh Networks" and "Measurements" respectively, and the student poster and demo session. The second day includes four technical paper sessions on "Sensor Networks I," "Wireless LANs," "Cellular Networks," and "Wireless Fundamentals" respectively, and one student poster competition session. The last day of the conference includes three technical paper sessions on "Sensor Networks II," "New Topics," and "Ad Hoc Networks" respectively, and one panel on "Wired vs. Wireless Access: The Race to Higher Speeds" organized by M. Sentinelli from Telecom Italia and several panelists from Ericsson, Cisco, Verizon, Qualcomm, Cingular, and Sprint.

While the schedule is quite tight to pack 35 papers in 9 technical sessions, the audience participated actively in the conference throughout the entire three days. Many presentations have elicited very enthusiastic discussions during and after the talk. The poster/demo session and panel in particular have attracted the attention of many participants. I have also acquainted myself with several distinguished fellow researchers during the breaks and the conference banquet, and discussed the possibility of research collaboration in the future.

二、與會心得

This year, the MobiCom Best Student Paper Award goes to “A Measurement Study of Vehicular Internet Access Using In Situ Wi-Fi Networks” by V. Bychkovsky, B. Hull, A. Miu, H. Balakrishnan, and S. Madden at MIT. This paper presents the results of a measurement study carried out over 290 “drive hours” over a few cars under typical driving conditions, in and around the Boston metropolitan area. The authors identify the characteristics of network connections established through vehicular Internet access such as throughput, loss rate, connectivity duration, and association latency, and then discuss solutions that can potentially be used to address problems in such a network. The topic of this paper is in line with this NSC project on vehicular ad hoc networks, and the proposed solution of this project also aims to maximize the duration of connectivity and minimize packet loss rates for connections established through vehicular networks. The problem investigated and the solution proposed by this project thus is important and timely.

In addition to research papers in 802.11 and mesh networks, there are also two sessions on wireless sensor networks. These papers cover a broad spectrum of topics including localization algorithms, information brokerage, routing algorithms for underwater sensor networks, boundary recognition, and synchronization techniques for multi-channel MAC in wireless sensor networks. Another session on cellular networks has also been allocated in the conference, with papers addressing various issues such as attack mitigation in SMS-capable cellular networks, application-aware acceleration for wireless data networks, and metastability and TCP-aware resource allocation in CDMA cellular networks. Therefore, it can be observed that MobiCom has a quite balanced selection of research topics in wireless networking.

Another interesting session in this year’s MobiCom is one that addresses “new topics” in wireless networking. This session includes papers such as “Fast and Reliable Estimation Schemes in RFID Systems” by M. Kodialam and T. Nandagopal from Bell Labs, “Coverage and Connectivity in Three-Dimensional Networks” by S. Alam and Z. Haas from Cornell University, “Physical-Layer Network Coding” by S. Zhang, S. Liew, and P. Lam from the Chinese University of Hong Kong, and “Low-Cost Communication for Rural Internet Kiosks Using Mechanical Backhaul” by A. Seth, D. Kroeker, M. Zaharia, S. Guo, and S. Keshav from the University of Waterloo in Canada. These papers introduce different new topics that have not been considered in related work and present pioneering work to address these problems.

Overall, while each year MobiCom accepts only about 30 papers submitted from top research groups all over the world, the gathering of top-of-the-line researchers and the organization of the conference program have made MobiCom a “must-go” conference for researchers to meet and interact with distinguished fellow researchers, and to seek timely, state-of-the-art research achievements. It is believed that for a high-quality conference like MobiCom, domestic researchers should be encouraged to attend for extending the viewpoint for world-class research and increasing visibility in the international research community.