

Wireless Channel Measurement and Network Bonding Emulation for Mobility Systems

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KEY WORDS: Information, communication, and intelligent systems,
Vehicle to everything communication, Communication system, Network Bonding, Field Testing (E2)

Aiming for a society with zero traffic accidents, research and development in connected (V2X) technology are being actively pursued to realize advanced driving assistance and autonomous driving. In recent years, technological development toward the realization of Level 4 autonomous driving has been accelerating, facilitated by initiatives such as field demonstrations on the Shin-Tomei Expressway. V2X encompasses V2V, V2I, V2N, and V2P. V2N, utilizing existing cellular networks, is currently leading in deployment with services like e-Call. However, dependence on single cellular carriers poses connectivity and capacity challenges for advanced services such as Level 4 autonomous driving. In this paper, we introduce network bonding technology that utilizes multiple carriers and multiple communication interfaces. Additionally, to examine the control methods required for the implementation of network bonding, we propose a network bonding emulation system capable of predicting the effects of network bonding. By utilizing past measurement data for the emulation, it becomes possible to evaluate control methods based on real-world environments.

Network bonding is a technology that combines multiple communication lines or network interfaces (NICs) and treats them as a single logical line. It is widely used in wired networks, such as those in servers and data centers, for the purposes of increasing communication speed, load balancing, and providing redundancy. When applying network bonding to mobility systems such as automobiles, wireless interfaces must be used, which makes control difficult due to the inherent instability of wireless communication. Therefore, a key challenge is to perform meticulous network bonding control based on the quality of these wireless interfaces. We define three modes for network bonding control: switching, aggregation, and diversity. The switching mode switches between wireless interfaces according to link quality, and is used to avoid latency or disconnection caused by issues such as packet errors. The aggregation mode bundles multiple wireless interfaces, which is used to achieve high-capacity communication by increasing throughput proportional to the number of bonded interfaces. The diversity mode transmits identical traffic over each wireless interface, which is used for applications requiring high reliability by providing redundancy to enhance communication robustness. In studying network bonding control schemes, simulation-based evaluation is common; however, there is a risk that the evaluated control schemes may not function as intended due to differences between the simulation environment and the real world. To address this, in this paper we propose a network bonding emulation method that uses previously measured wireless interface quality to predict the effects of network bonding and evaluate control schemes.

Using the cellular measurement system we developed, we conducted drive tests in urban Los Angeles to measure the wireless interface quality of the three major North American carriers. From the measurement results, we confirmed that even along the same driving route, communication quality (throughput) varies by carrier. We then performed emulation to predict the effects of network bonding using the measured data. Figure 1 shows the emulation results. From these results, we confirmed that in areas where the aggregation mode is applied, summing the throughput of each carrier yields a predicted throughput that exceeds the communication quality achieved when communicating via a single carrier. On the other hand, in areas where the diversity mode is applied, the line with the best communication quality (measured throughput) at each moment is selected, thereby reducing the impact of fluctuations in communication quality and enabling the system to always choose the best line in the face of throughput variations occurring on each carrier.

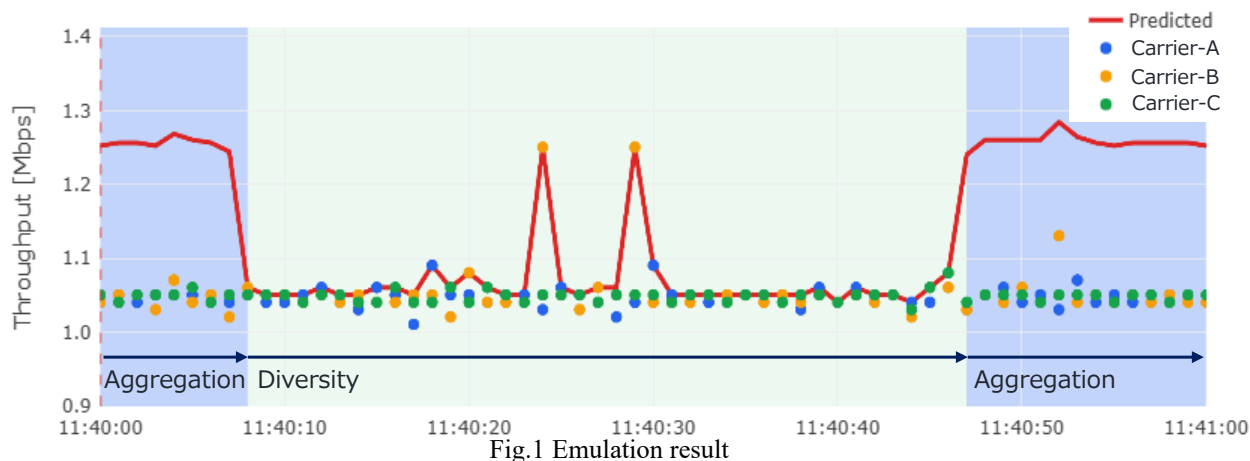


Fig.1 Emulation result