

Network Bonding Field Testing for Mobility Systems

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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. This paper presents a network bonding technology for mobility systems equipped with multiple carriers and communication interfaces. Field testing results from our experimental system demonstrate that network bonding significantly improves communication stability in terms of both connectivity and capacity.

Fig. 1 shows the network bonding architecture. The network bonding is configured between routers installed in the mobility system and the server, and is controlled by the network control functions implemented in each. We define three modes for network bonding control: switching, aggregation, and diversity. The switching mode switches between wireless interfaces according to the link quality, which 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.

Network bonding is a technology that bundles multiple communication lines or network interface cards (NICs) into a single logical connection. It is widely utilized in wired networks, such as those in servers and data centers, for the purposes of increasing bandwidth, load balancing, and redundancy. However, applying network bonding to mobility systems, such as vehicles, presents significant challenges due to the inherent instability of wireless interfaces. Consequently, achieving precise network bonding control based on wireless link quality is essential to maintaining reliable communication. While it is common practice to perform network bonding control by monitoring wireless interface quality—similar to methods used in wired networks—this reactive approach has a drawback. Specifically, responding to fluctuations in wireless quality often leads to communication quality degradation during the latency period before the control is fully executed, which may result in network disconnection. Therefore, in this paper, we propose a proactive network bonding control method. By pre-measuring the wireless interface quality along a planned route, our method executes control based on these measurements, thereby preventing quality degradation and ensuring seamless connectivity.

To validate our proposed method, we conducted field tests on a course approximately 4.8 km in length around Shin-Kawasaki Station. When using a single carrier (Carrier-A) alone, a throughput drop was observed in the vicinity of Shin-Kawasaki Station. In contrast, no such degradation occurred when using our predictive network bonding control. This is attributed to the fact that the system successfully switched to Carrier-B or Carrier-C, thereby avoiding the impact of the quality degradation experienced by Carrier-A. Furthermore, we observed no transient quality degradation typically associated with reactive (post-event) control, confirming that stable communication can be achieved in terms of both connectivity and throughput.

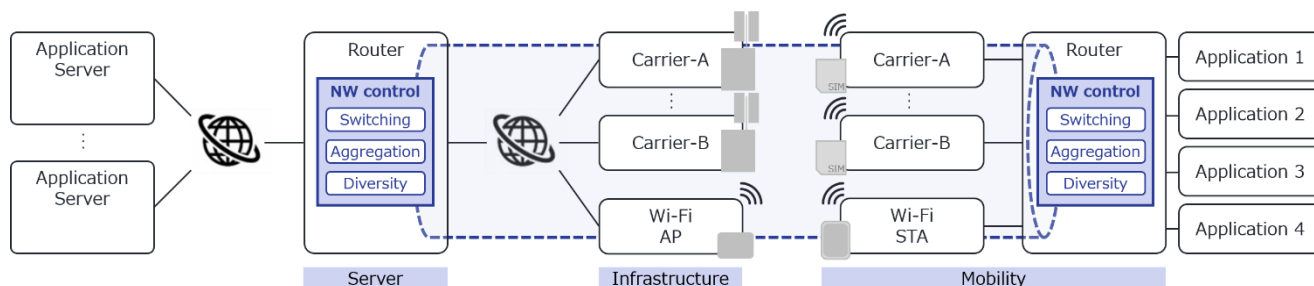


Fig.1 Architecture of Network Bonding