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Multi-Element Free-Space-Optical Modules for Mobile Opportunistic Networking

As the RF spectrum is getting scarcer, there is an urgent need for innovations that will allow new and complementary wireless spectrum bands in both military and civilian settings. Recent research has shown that free-space-optical (FSO), a.k.a. optical wireless, communications is a promising complementary approach to address the exploding mobile wireless traffic demand. FSO transceivers are cheap, small, low weight (less than 1gm), amenable to dense integration (1000+ transceivers possible in 1 sq ft), are very long lived/reliable (10 years lifetime), consume low power (100 uW for 10-100 Mbps), can be modulated at high speeds (1 GHz for LEDs and higher for lasers), and offer highly directional beams for spatial reuse/security (1-10 uRad beam spread). Its unlicensed huge spectrum and low power-per-bit properties of FSO communications makes it a great opportunity for future spectrum-scarce mobile networks and power-hungry Internet-of-Things (IoT) systems. Low-intercept characteristics of FSO due to its high directionality and physical containment in closed rooms are also attractive for secure wireless communication applications. Lastly, potential integration with solid-state lighting technology presents an attractive commercialization possibility in the long run. However, FSO communication suffers from beam spread with distance and unreliability during bad weather. Further, the major impediment for using FSO in a mobile setting is the line-of-sight (LOS) alignment requirement.

Our existing efforts have pointed to the possibility of employing FSO within the context of mobile ad-hoc networking by handling its mobility and range issues via multi-element and multi-hop designs. Our prior work in mobile FSO networks has produced a prototype of an LOS alignment protocol that can handle mobility via multi-transceiver spherical modules. Such modules can provide two key features: (i) high spatial reuse due to high directionality of individual FSO transceivers' communication beam and (ii) angular diversity due to their spherical shape. The alignment protocol effectively steered (i.e., detected and handed off) multiple simultaneous data transfers to the transceivers on two neighboring modules. We believe that further research in multi-element FSO modules is necessary to enable the optical spectrum bands in mobile settings, and argue that there is need for multi-disciplinary efforts -- spanning device-level issues (e.g., solid-state packaging) to transport and application level issues (e.g., reliable end-to-end transfers over highly intermittent FSO links).