Advancement of space technology together with the sophisticated space-based instruments opened a new chapter for optical space-based communication. This is also due to increasing demand for large communication capacity and reliable communication links in satellite communication systems (SATCOM) systems. Currently, most of the existing SATCOM systems are based on radio frequency (RF) links, where the data rate is limited to a few hundred megabits per second (Mbps). Hence, the time has come to consider other possible options for SATCOM, which can cater the needs of data-heavy links. In recent years, a growing interest has been witnessed in the research and development of establishing free space optical (FSO) links between ground station (GS) and satellite, which can offer much larger data rates up to several gigabits per second (Gbps). FSO, which is the term used for optical wireless communication in outdoor scenario, refers to a line of sight communication between two fixed points in the atmosphere (or free space) using optical carriers. FSO communication has garnered significant importance owing to its unique features: cheap installation cost, unlicensed spectrum, highly secure system due to line-of-sight operation, relatively high bandwidth, etc. However, FSO supports high data rate only for short-range transmission and the performance of GS-to-satellite FSO link is limited by the adverse effects of the atmospheric turbulence induced fading, attenuation due to fog, and beam-wander induced pointing errors. Therefore, in order to improve the performance of FSO-based SATCOM system, it is wise to backup FSO links with more reliable RF links, as they are less susceptible to fog, atmospheric turbulence, and pointing errors. Meanwhile, FSO and RF channels exhibit complementary characteristics to weather conditions. Specifically, the performance of the FSO link deteriorates significantly due to fog. On the contrary, the RF link performance degrades due to rain. These two complementary characteristics pave the way for hybrid FSO/RF communication. Moreover, high-altitude pseudo-satellite or high-altitude platform station (HAPS) can act as a relay station between satellite and GS to further enhance the performance of GS-to-satellite FSO link. HAPS are aircraft or airships situated well above the clouds at typical heights of 17 to 32 km, where the atmospheric impact on an optical beam is less severe than directly above ground. The main advantages of HAPS are less propagation delay, easier and faster deployment than satellite, medium operational costs, and environmental friendliness. In a nutshell, a comprehensive performance analysis of the HAPS-based hybrid FSO/RF SATCOM system over varying weather and atmospheric turbulence conditions with pointing errors will be carried out. From the performance analysis, the performance gain obtained due to backup RF links and HAPS compared to the existing single-hop FSO-based SATCOM systems will be reported.
• To propose novel system models using high-altitude platform station (HAPS) utilizing both free space optics (FSO) and radio frequency (RF) links for improving the reliability of ground station (GS)-to-satellite and satellite-to-GS FSO links.
• To propose novel switching schemes for HAPS-based hybrid FSO/RF communication such that the message signal can be transmitted via FSO or RF links or both.
• To investigate the performance of the proposed hybrid system by deriving theoretical expressions for the performance parameters such as average symbol error probability, average outage probability, and ergodic capacity and validating the same using Monte-Carlo simulation results.
• To obtain capacity bounds and asymptotic expressions in order to get more insights in terms of achievable capacity and diversity gain.

**Development of Landslide Early Warning and Real-time Monitoring, Uttarakhand**

Real-time wireless sensor network (WSN) is an emerging technology for landslides monitoring. Rainfall-induced landslides are one of the most destructive natural disasters. WSN system works aggressively and it relies mainly on solar power to recharge the power system. However, during torrential rain-fall period, the rate of recharging is absolutely zero. Moreover, sensor node cannot be equipped with high capacity batteries due to its size limitations. Apart from that radio frequency (RF) link reliability, connectivity issues due to adverse weather conditions and increase in communication latency due to transmission of overheads are also other challenges faced by WSN during landslide monitoring. Hence, to counteract the mentioned limitations, various communication techniques such as cooperative communications, massive multiple-input-multiple-output (MIMO), energy harvesting and non-orthogonal multiple access (NOMA) will be proposed. The study is aimed to perform the following objectives.

• To design efficient WSNs for landslide monitoring using the above-mentioned communication techniques.
• To investigate the performance of the proposed networks by deriving theoretical expressions for the performance parameters and validating the same using Monte-Carlo simulations and real-time hardware testbeds.