INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student	:	Aparna Mishra
Roll Number	:	206102006
Programme of Study	:	Ph.D.

Thesis Title: Performance analysis of coexistence based integrated communication and sensing systems.

Name of Thesis Supervisor(s)	:	Dr. Ribhu
Thesis Submitted to the Academic Division	:	EEE
Date of completion of Thesis Viva-Voce Exam	:	10.11.2025
Key words for description of Thesis Work	:	Integrated communication and sensing, massive MIMO, MIMO radar, performance analysis, radar communication coexistence, stochastic geometry, and intelligent reflecting surfaces.

SHORT ABSTRACT

Intelligent transportation systems (ITSs) have emerged as a promising technology to address two major challenges in the road transportation system; road accidents and traffic congestion. ITS require smart vehicles to provide both radar and communication capabilities. This in turn requires a large bandwidth for the effective deployment of both. However, the bandwidth and space constraint at vehicular terminals poses a major challenge for the effective deployment of ITS.

The advancements in wireless communication technology have led to the development of integrated communication and sensing (ICS) systems. These type of systems are designed to share either spectrum or hardware, or both, and thereby reduce the overall cost of the system. It has been argued that these systems can be broadly classified into three categories, viz.; radar communication co-existence, where both the radar and communication sub-systems operate independently; radar communication co-operation, where they coordinate to reduce mutual interference; and radar communication co-design, where they share common hardware and process their signals to mitigate mutual interference.

Both the co-operation and co-design based ICS systems aim to improve the performance of the radar and communication functionalities, however, they are incompatible with legacy systems. Therefore, in this thesis we investigate co-existence based ICS systems.

In coexistence based ICS systems, we consider that both the radar and communication sub-systems do not share any information, and treat each other as interference sources. Therefore, we investigate the overall system performance and that of each sub-system in the presence of interference generated by the other sub-system. The first problem we address in this thesis entails the analysis of a single cell massive multi input multi output (mMIMO) communication system in coexistence with a mono static multi input multi output (MIMO) radar. Here, considering that the presence of radar is known at communication base station (BS), we analyse the performance of the ICS system under three communication subframes viz. the channel estimation subframe, the uplink and the downlink transmission subframes. During the first subframe, the BS performs uplink channel estimation in the presence of radar generated interference and we derive the corresponding mean square error (MSE) expression. Further, during the second subframe, using these estimates, the BS performs minimum mean square error (MMSE) combining and we obtain the expression for uplink achievable rate via deterministic equivalent (DE) analysis. Following this, in the downlink communication sub-frame, the BS performs null space projection to eliminate the communication interference at the radar sub-system. We derive the expression for Crammer Rao Bound (CRB) on the radar's angle of arrival (AOA) estimation error in both the uplink and downlink communication subframes and utilize the notion of radar rate to measure the performance of radar and communication system on the same scale and obtain rate regions for both uplink and downlink communication sub-frame.

Following this, we analyse the performance of a cell free massive multi input multi output~(CF-mMIMO) communication system in coexistence with a multi-static tracking radar. CF-mMIMO is a key enabling technology for the air interface of next generation wireless communication systems due to its attributes, including uniform coverage, high power scaling and energy efficiency. Here, we analyse the performance of both the radar and communication subsystems in the uplink communication frames. The radar subsystem performs two stage target tracking at each sensing instant using the extended Kalman filter (EKF) algorithm. During the uplink channel estimation subframe, the BS estimates the uplink communication channels in the presence of radar generated interference, and we derive an expression for uplink achievable rate using these estimates. Through numerical simulations, we observe that a multi-static tracking radar can coexist with a CF-mMIMO system without any significant loss. We further extend this model to a stochastic geometry framework to consider a more realistic wireless environment and analyze the performance of both the subsystems.

Finally, we examine an intelligent reflecting surface (IRS) enabled communication system and a MIMO radar in coexistence with each other in millimeter wave (mmWave) spectrum. We derive the best case and the worst case CRBs on the AOA estimate at the radar sub-system in the presence of communication interference, and obtain an expression of uplink achievable communication rate in the presence of radar generated interference. Through extensive simulations, we observe that IRS improves the performance of communication subsystem while the effect of IRS on the radar performance can be ignored and concluded that IRSs barely degrade the performance of the radar subsystem and at the same time improve communication system performance, enabling coexistence.