# INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
## PhD-17 SHORT ABSTRACT OF THESIS

| | |
|---|---|
| **Name of the Student** | : Adri Bhattacharya |
| **Roll Number** | : 206123002 |
| **Programme of Study** | : Ph.D. |
| **Thesis Title** | : Distributed Algorithms for Treasure Hunt and Variations of Black Hole |
| **Name of Thesis Supervisor(s)** | : Prof. Partha Sarathi Mandal |
| **Thesis Submitted to the Academic Division** | : 14th November 2025 |
| **Date of completion of Thesis Viva-Voce Exam** | : 25th February 2026 |
| **Key words for description of Thesis Work** | : Treasure Hunt, Black Hole, Byzantine Black Hole, Mobile Agents, Distributed Algorithms |

## SHORT ABSTRACT


In the last decade, designing distributed algorithms for mobile entities (such as mobile agents) has garnered a lot of interest. There are many fundamental problems in this domain, among them our focus in this thesis has been on *search* and *exploration* problems. The thesis diversifies from an underlying topology being a continuous domain (such as the Euclidean plane) to a discrete domain (i.e., a graph network). Under the graph networks, the thesis focuses on both static as well as dynamic graphs. The first two problems broadly fall under the class of *search* problems.

In the first problem, we study the treasure hunt problem, where the mobile agent is required to find an inert target (or treasure) in an unknown environment. We study this problem in the Euclidean plane, where a mobile agent finds the treasure with the help of pebbles. The treasure is situated at a distance of at most $D$ ($> 0$) from the initial position of the agent. An Oracle, knowing the treasure's position and the agent's initial location, places some pebbles to guide the agent towards the treasure. The agent has no knowledge about the treasure's position or how many pebbles are placed and where they are placed. Here, in this problem, we raise the following question and answer it: "For given $k \geq 0$, what is the most efficient treasure hunt algorithm if, at most, $k$ pebbles are placed by the Oracle?"

In the second problem, we study the black hole search problem by a team of mobile agents. A black hole is a dangerous stationary node in a graph that eliminates any visiting agent without leaving any trace of its existence. Key parameters that dictate the complexity of finding the black hole include the number of agents required to locate the black hole, the number of moves

performed by the agents and the time taken to determine the black hole location. We study this problem when the underlying topology is a dynamic cactus. We introduce two models of dynamicity: we examine the scenario when the underlying graph has at most one dynamic edge, and secondly, when the underlying graph can have at most $k$ dynamic edges. In both these cases of dynamicity, the only constraint is that the underlying graph must be connected, irrespective of which edge (or edges) are dynamic. The choice of edge (or edges) to be dynamic at a certain round is determined by the adversary. For each of these two cases, we have established lower and upper bounds on the number of agents, moves and rounds required to find the black hole.

The following two problems fall under the class of *exploration* problem. In both of these problems, we study perpetual exploration in the presence of a malicious node that is more powerful than a black hole, in terms of maliciousness. We call this version of a more powerful black hole a *Byzantine black hole* or, in short, a BBH. In our third problem, we study perpetual exploration of a static synchronous ring in the presence of a BBH. We investigated this problem for any arbitrary starting configuration of the agents (i.e., the agents can be either co-located or scattered). Next, for each of these starting configurations, we also looked into various communication models (such as *face-to-face*, *pebble* and *whiteboard*). The main objective in this problem is to emphasize minimizing the number of agents required to guarantee perpetual exploration under all these various conditions and in the presence of a BBH.

In the fourth problem, we answered the following question: "How can a group of initially co-located agents explore an unknown graph, when one stationary node occasionally behaves maliciously, under the control of an adversary?" In other words, we extended our earlier problem (which is confined to just static rings) to any arbitrary topology. Formally, we study this perpetual exploration problem in the presence of at most one BBH, without initial knowledge of the network size. Since the underlying graph may be 1-connected, perpetual exploration of the entire graph may be infeasible. Accordingly, we define two variants of the problem, termed as PERPEXPLORATION-BBH and PERPEXPLORATION-BBH-HOME. In the former, the agents are tasked to perform perpetual exploration of at least one component, obtained after the exclusion of the BBH. In the latter, the agents are tasked to perform perpetual exploration of the component that contains the home node, where agents are initially co-located. Naturally, PERPEXPLORATION-BBH-HOME is a special case of PERPEXPLORATION-BBH. The mobile agents are controlled by a synchronous scheduler, and they communicate via *face-to-face* model of communication.