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**Ph.D. Research Proposal**

**Doctoral Program in "Department Name"**

# Power Aware Secure and Scalable Model for M2M Communication Assisted Smart City Applications

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## I. INTRODUCTION / BACKGROUND

In Internet of Things (IoT), Machine to Machine Communication (M2M) is the hot research field. Machine Type Communication (MTC) devices in 5G networks are associated to battery constrained which requires efficient resource allocation. A threshold controlled access protocol is designed for uplink resource allocation with the guarantee of quality of service (QoS) [1]. MTC devices in 5G is associated with internet of things (IoT) in which massive number of devices are participating into it under a variety of application. QoS metric also includes throughput, delay and energy consumption as its individual constraints. In [4], throughput optimization is focused by addressed the optimal back-off value selection. Due to the involvement of multiple devices, traffic is one of the major constraint that is taken into account [14]. A delay-aware time slot assignment model is proposed for achieving QoS by considering priority based on their data types [13]. Priority based on the type of device, may not satisfy all the devices QoS in a system. In [2], the devices are categorized into four types based on which they are prioritized for resource allocation. This work utilizes combination of 3G and LTE technologies for ensuring lossless QoS in the network. Power control is assisted with the improvement of quality of experience (QoE) by estimating combination of outage probability and density for allocating resource blocks [6]. In this work resources are allocated between devices and enrich QoE of the system.

A hybrid MAC protocol is designed by integrating contention process and transmission process using the combination of slotted-ALOHA and TDMA mechanism [7]. The versions of ALOHA is incorporated and then conventional procedure of equal timeslots is used for data transmission as in TDMA. This M2M communication into smart city environment deals with the minimization of access collisions using delay based priority assignment [12]. The two types of requests are delay-sensitive and delay-tolerant. However, some requests are rejected due to non-sensitive to delay. A collision-aware resource access scheme is proposed [8]. In this work a special field of flag is included to intimate the occurrence of collision in the access request.

A fair and efficient allocation of resource is proposed in [9] that use Nash bargaining solution based on cooperative game for network resource allocation. A utility function is determined in accordance with the achievable rate for resource allocation. In [10], an efficient MAC is designed for M2M communication by using TDMA strategy for transmission of packets. In order to increase the performance of MTC, a novel random access scheme is proposed with virtual preambles [11]. A contention based random access is addressed for mitigating collision probability and access delay. In [15], multi-slot allocation protocol is developed with the selection of seed by consecutive iteration until the time bound is attained. The appropriate selection of seed value enables to allot multiple slots for data transmission. An efficient MAC protocol design focuses on power constraint in M2M communication [15]. Most of the works have discussed with MAC design for M2M communication, whose critical problems are investigated in next section.

### 1.1 Research Outline & Scope

**A** proper security and storage schemes will bring a new level of innovation to this M2M Communication. The growth of IoT lies mainly in the security of the implementation. In addition, adaptive MAC enabled M2M communication must support for QoS improvement.

### 1.2 Research Objectives

The M2M communication is performed in very less human intervention and limited resources. The design of priority based MAC is enabled to support QoS and to reduce the amount of power while design of massive i.e. scalable environment for MTC devices.

## II. RESEARCH GAPS

### 2.1 Common Problem Statement

In the future cyber-physical system (CPS), all objects in cyber world and physical world would be connected, and the concepts of cyber world and physical world will no longer exist. The speed of information transmitting and processing will be faster, the abilities of controlling facilities and handling events will be more powerful, and our lives will be better. In the CPS, machine to machine (M2M) communication is in charge of data collecting and transmitting,

which utilizes both wireless and wired systems to monitor physical or environmental conditions and exchange the information among different systems without direct human intervention. As a part of CPS, M2M communication is considerably important while being fragile at the same time because M2M communication still faces lots of security threats that are not only from outside but also from inside. In traditional M2M communication, the M2M service provider (MSP) is always assumed to be trusted. However, the MSP could be compromised in real world. In that case, the previous security solutions would fail because the most confidential materials are kept in the MSP by the conventional solutions. How to protect the entire system from the compromised MSP is one important problem the paper intends to solve.

### 2.2 Problem Definition

The authors of this paper have proposed [16] M2M opportunistic splitting algorithm (M2M-OSA) for allocating uplink resources in distributed manner. Then the number of backlogged users is estimated for improving effectiveness of the network. The initial step in this M2M-OSA is the random selection of resource blocks for competition. Every UE is given with maximum retransmission limit, within which the device is allowed to request for resource. The UE uses two known threshold values based on the number of contending devices, if condition satisfied UE request BS. If the feedback from BS is collision, then the threshold is updated similarly using upper and split functions. The active devices are estimated by summing up newly arrived devices and backlogged devices present in prior slots.

**Problems** –

- Random selection of resource blocks leads to under-utilization of resources and also it results with failure.
- The threshold value for request is updated only after collision feedback is received.
- Each individual M2M device requests for resources, which makes the system complex as per the increase in number of devices.
- Testing on small sized data is not applicable for real-time data transmission application.

**Proposed Solutions –**

- Only MTCH approaches eNB for resources, which reduces the complexity and ensures scalability in large-scale environment.
- Appropriate allocation of resources based on the improved TDMA slots
- Collision is reduced by hierarchical level based preamble assignment
- Guaranteed QoS

A cluster based congestion mitigating access scheme (CCAS) is proposed in [17], which constructs cluster using modified spectral clustering algorithm. The consecutive processes performed in this paper are MTCD clustering, MTCG selection and data transmission. Clusters are constructed by measuring joint similarity that takes in account of location and delay requirement. In this clustering, initially similarity is estimated, then spectral clustering used to determine diagonal matrix, laplace matrix eigen values and eigen vectors which is given into K-means clustering for cluster formation. MTCG is chosen with the estimation of delay requirements and energy consumption.

**Problems** –

- Larger time for clustering due to the processing of spectral clustering and then K-means clustering.
- The packet from MTCD to MTCG is not transmitted until the buffer threshold is attained.
- CSMA/CA is adapted for mitigating collision; however, it consumes larger power consumption.

**Proposed Solutions** –

- Head is selected and then grouping is performed that mitigates the processing time.
- Data transmission from MTCH transmits the data without waiting for the buffer to be filled.
- Power consumption in CSMA/CA due to random back-off time is resolved by computing back-off time based on aggregate function and delay.

In [18] author proposes a power adaptive methodology that follows processing in two phases as: phase 1 power adaptive slotted Aloha (PASA) MAC protocol and phase 2: spectrum provisioning for devices. These two phases are performed with the aim of minimizing energy consumption. The contention window size is adjusted with respect to power and delay. Power value is determined from Random-access channel (RACH) and delay is composed of retransmission delay, propagation delay and packet transmission delay.

**Problem –**

- Delay time was computed based on three metrics which were measured from previous transmission. Hereby the computation of delay in accordance with prior transmission is not appropriate for estimating current window size, since the signal characteristics are dynamic.
- In slotted ALOHA, the data transmission has to be started from the beginning of the slot, if missed then the M2M has to wait for next slot. Also if more than one M2M tries to use same slot then collision occurs.

**Proposed Solutions –**

- Dynamic switching of MAC enables reduction of collision which is decided based on the network characteristics.
- For back-off based on contention window size is given based on aggregate function and delay.

The authors of this paper have proposed [19] an energy efficient scalable MAC protocol for larger number of M2M devices. The designed MAC protocol is composed of contention interval (CI) and data transmission interval (DTI). The CI for channel access and DTI are for data transmission on the time-slots. Hybrid MAC protocol is a combination of contention-based and reservation-based schemes. DTI follows TDMA scheme which has equal sized timeslots.

**Problem** –

- TDMA based data transmission is not suitable for large scale environment; hence the scalability degrades with the increase in number of M2M devices.

- This scheme is asynchronous; using TDMA requires time synchronization among M2M devices. Else it introduces overhead.

**Proposed Solutions** –

- Adaptive CDMA and TDMA is proposed that allots time based on significant constraints and the time synchronization problem in traditional TDMA is resolved by using Function Rewards based HMM for time synchronization.

The problem of congestion is concentrated in this work [20], which is resolved by using Q-learning approach as a random access channel scheme. In this approach, the demand for M2M communication, H2H communication, state-action pairs and rewards are taken in account. In case, if the estimated reward is positive, then H2H devices are assigned with larger number of preamble else if the reward is negative, then the M2M devices are assigned with larger number of preambles. As a result, this Q-learning approach determines number of preambles for both M2M and H2H communication traffic.

**Problems** –

- In this work, the Q-learning determines only the number of preambles which are assigned to M2M and H2H.
- Traditional Q-learning consumes larger time in optimal Q-value prediction due to the requirement of larger number of iterations for computing rewards.

**Proposed Solutions** –

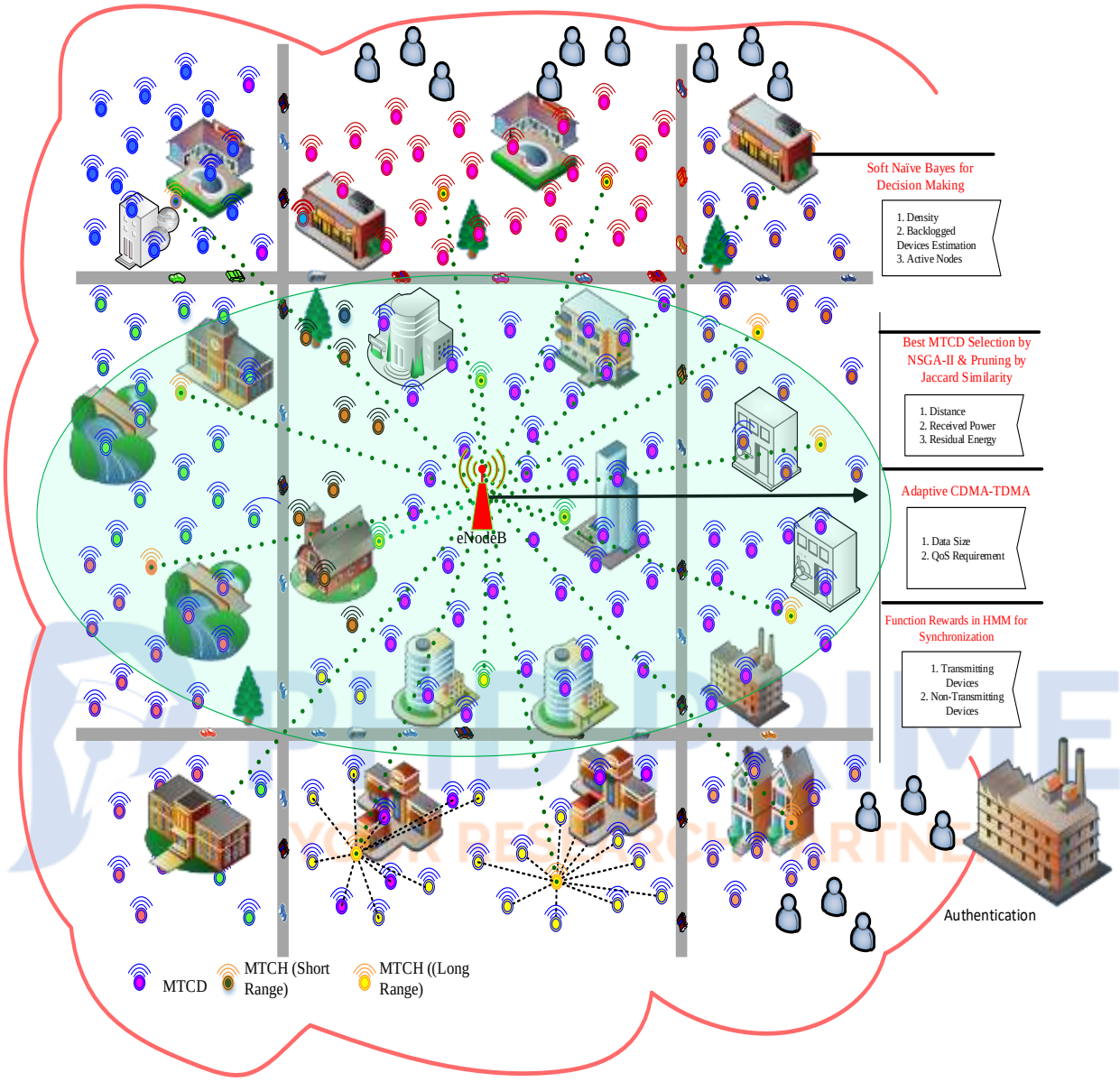
- Using CSMA TDMA MAC verifies if there any collision and then it requests via RACH. Also in this proposed work, the channel stability is also checked and then level based preamble utilization ensure to reduce collision.

- The process in proposed LTE—MTC is performed without any iterations, it is operated timely.

## III. RESEARCH CONTRIBUTIONS

The proposed power efficient scalable MAC protocol designed for M2M communication is composed of Machine Type Communicating devices (MTCD) and eNodeB (eNB). These MTCD are incorporated to participate in Internet of Things (IoT). Power is effectively minimized with congestion-less slots assignment for data transmission.

## SYSTEM ARCHITECTURE




This proposed system of MTC in LTE is addresses with the problems of higher collision, delay, poor security and scalability and not able to guarantee QoS in the network. Hereby, the proposed MTC-LTE is composed of processing in four steps as Secure Authentication, Grouping, Dynamic MAC Utilization and Slots allotment. The MTCD are enabled to support IoT and hence the MTCD are assumed as sensors deployed in a smart city environment. The three phases are detailed in the following,

**M2M Devices Authentication**

Initially, the M2M device will send its ID and a random number to the server. After verification, the server provides its ID and a random number back to the mobile device through Pseudorandom Function. After verification the session key is established. Within this session period, the mobile devices can transfer or access the data.

**M2M Devices Grouping**

Then, the MTCD are grouped by initiating the group head selection process. NSGA-II is incorporated for optimal head selection based on three metrics as distance between MTCD and eNB, received power and residual energy of MTCD. The pruning is held by Jaccard Similarity. The entire coverage rage of eNB is selected with hierarchical MTC-heads (MTCH) in increasing levels of communication range. MTCH are elected by eNB and then the MTCD are included into groups by exchanging Join-Request and Join-response message in short range communication. Grouping of MTCD guarantees QoS and power efficiency.

**Dynamic MAC Utilization**

Dynamic MAC utilization is incorporated in this phase for allotting resources for winning MTCH. The two MAC protocols used here are CSMA/CA and CSMA/CARP, whose decision is taken using estimation of probability values based on density, backlogged devices and active nodes. Once the decision is made, then the MTCH prefer a channel with higher stability and bandwidth.

In MAC protocol, the use of same preamble by more than on MTC tends to cause collisions, which is reduced by assigning sets of preamble for each levels of MTCH, so that only those preambles can be chosen for requesting. On receiving connection request, eNB verifies for the availability of the residual resources and then allots resources for data transmission. The enhanced CSMA/CA is deployed with estimation of new back-off time that taken in account of aggregate function, delay and active MTCD in particular group. In some cases random waiting time consumes larger time in waiting. Then CSMA/CARP allots priority based resources with

respect to the channel capacity and residual energy. Back-off time is determined after occurrence of collision which is not computed based on random time as in conventional CSMA, it is determined from aggregate function and delay.

**Adaptive TDMA (ACDMA-TDMA)**

In phase III, the MTCH are allotted with time slots using adaptive CDMA and TDMA which assigns time by estimating size of data and QoS requirements. The size of the data denotes the composition of all data collected from MTCD in that group. The QoS requirements include satisfactory throughput and average access delay. The ACDMA and TDMA is associated to be operated in synchronized time using Markov chain model. From the prediction of states in this model, the time synchronization in ACDMA-TDMA is achieved which is one of major problem in traditional TDMA.

**Performance Evaluation**

Hereby the performance of the proposed system is experimentally evaluated in terms of following parameters,

- No of devices vs. Average access delay
- No of re-transmission vs. Average access delay
- Average energy
- Probability of collision
- No of successfully received packets
- No of clusters

## IV. RESEARCH NOVELTIES

The proposed novel solutions are supposed to resolve power and efficient MAC in terms of the following aspects,

- Firstly, grouping of MTCD mitigates power i.e. not all the MTCD access eNB, only the authorized MTC devices and also corresponding heads only requests eNB which

mitigates power and congestion. Grouping is also presented to guarantee Quality of Service in the network.

- Secondly, most of the previous work has focused to follow any one MAC, hereby in this proposed work switching of MAC protocol is introduced based on significant constraints elaborated.
- Lastly, appropriate timeslot assignment for data transmission

## V. PREVIOUS WORKS & LIMITATIONS

**Paper 1**

**Title** – Delay-Aware Resource Allocation for M2M Communications Over LTE-A Networks

**Concept** –

In this paper, the authors have developed a delay-aware time-slotted resource allocation with priority-based queuing model. Both H2H communication and M2M communication are concentrated in this work, in which H2H is provided with higher priority and M2M with lower priority. Different data types are addressed in this work, since the QoS requirement is not similar for individual data traffic.

**Paper 2**

**Title –** Service Time-Based Region Division in OVSF-Based Wireless Networks with Adaptive LTE-M Network for Machine to Machine Communications

**Concept** –

In this paper LTE technology is enabled for IoT applications in which the resources are assigned with orthogonal variable spreading factor (OVSF). Resources are allotted based on the device priority, that is defined into four types. Both 3G and LTE are used, in which 3G is for smaller data transfer and LTE is for larger data transfer. If the resources in 3G are not sufficient then it is provisioning by LTE in this work.

**Paper 3**

**Title** – Network Dimensioning, QoE Maximization and Power Control for Multi-Tier Machine-Type Communications

**Concept** –

The authors of this paper have proposed network dimensioning and radio resource partitioning for data forwarding from MTCD to base station (BS). The quality of experience (QoE) is maximized by taking in account of outage probability constraint and minimum MTCD density constraints. The packets from MTCD are collected by MTC gateway and transmitted to BS via random requests procedure. Here, the resource blocks are allocated for MTCD-to-MTCD and MTCD-to-BS.

**Paper 4**

**Title –** Optimized approach based on hybrid MAC protocol for M2M networks

**Concept –**

The proposed hybrid MAC protocol is a combination of slotted-ALOHA and TDMA mechanism. Monte Carlo simulations are performed for retrieving optimized values of probability of successful contending and duration of transmission. The contention mechanism of non-persistent carrier sense multiple access with collision avoidance (NP-CSMA-CA), S-ALOHA and P-persistent carrier sense multiple access with collision avoidance (P-CSMA-CA). The optimization problems defined are probability of successful contending and duration of transmission. However, the optimization is presented the MAC used here is not based on any peculiar constraint. If time slots are available, then they are priorly reserved as TDMA slots for data transmission.

**Paper 5**

**Title –** Energy Efficient Resource Allocation for M2M Devices in 5G

**Concept –**

This paper proposes a QoS guaranteed technique named threshold controlled access (TCA) protocol. The proposed TCA protocol estimated threshold in accordance to QoS metric. Here the QoS is based on the power metric whose higher power rank is determined from power limit and transmit powers. The QoS metric is estimated and then threshold is chosen from interpolation function and then updates. This work is not studied for massive number of devices with allocation of resources.

**Paper 6**

**Title** – Fair and Efficient Rate allocation for Wireless-Powered Machine-Type Communication Networks

**Concept** –

The authors of this paper have designed a fair and efficient resource allocation in MTCD by solving Nash bargaining solution. The allocation of resources is based on the channel quality. The cooperative game problem is solved by the estimation of achievable rate for individual MTCD using utility function. The problem is solved with the selection of optimal duty cycle which is used for allocating resources. Then the minimum rated MTCDs are allotted with resources based on the differing channel conditions.

**Paper 7**

**Title –** An M2M computing model for improving the performance among devices

**Concept –**

IoT applications in M2M communications present data transmission with a couple of challenging issues into it. This M2M communication is enabled to integrate with other domains of network for processing and management of large amount of data. Hereby, this paper elaborates the M2M communication incorporated into IoT platform.

**Paper 8**

**Title –** Multi-Slot Allocation Protocols for Massive IoT Devices with Small-Size Uploading Data

**Concept** –

In this paper, the authors have employed extend eHint protocol for multi-slot data transmission in the network. The multi-slot allocation of communication channel deals with three process as broadcast, allocate and random. The previous two virtual frame (2VF) was filed to select a satisfactory seed when there is an increase in number of IoT devices. To solve this problem, an iterative-virtual-frame is presented that selects seed using iterative based on specified time bound.

**Limitations**–

- The initial seed values were considered randomly without taking in account of significant network constraints.
- Iteration for seed selection was performed only the time bound is reached, in case if an unsatisfied seed is resulted, then previous best seed was used. However, the time utilized for unsatisfied seed estimation degrades network performance.

**Paper 9**

**Title -** Energy-efficient power allocation for massive M2M communication over LTE-A cellular uplink

**Concept –**

The authors of this paper aim to mitigate signal overhead by increasing the energy efficiency among the groups of M2M devices. The data from MTCD is aggregated by MTCG and then forwards to BS. For power allocation, Lagrange multipliers is proposed to compute optimal transmit power for MTCD and MTCG.

**Paper 10**

**Title –** Modeling Reliable M2M/IoT Traffic over Random Access Satellite Links in Non-saturated Conditions

**Concept –**

This paper is proposed for M2M/IoT traffic based resource allocation in the system. The constrained application protocol (CoAP) is incorporated with selective repeat automatic repeat request and sender-based variant of TCP friendly rate control protocol. The proposed congestion control algorithm is evaluated with fairness among the competition flows.

**Paper 11**

**Title -** Efficient Random-Access Scheme for Massive Connectivity in 3GPP Low-Cost Machine-Type Communications

**Concept –**

This paper proposes a novel random-access scheme with the incorporation of virtual preambles. Unique virtual preambles create the opportunities of faster accessing with minimized access delay and collision. This virtual preamble is defined as the combination of preamble and PRACH indices. Markov chain model is presented for identifying the state transition of the ransom access requests. Hereby the selection of unique preamble ensure with the reduction of collision during access.

**Paper 12**

**Title –** Optimizing M2M Communications and Quality of Services in the IoT for Sustainable Smart Cities

**Concept –**

This paper proposes an admission control model with delay-sensitive and delay-tolerant first requests. The aim of this work is to mitigate number of requests submitted to access. If the request is not delay sensitive then it is aggregated, since only the delay sensitive packets are provided with higher priority to communicate with server. In this admission control algorithm, certain requests are rejected due to their delay constraint.

**Paper 13**

**Title** – Collision-Aware Resource Access Scheme for LTE-based Machine-to-Machine communications

**Concept** –

This paper proposes collision-aware resource access (CARA) scheme which aims to minimize collision. Once the preamble is selected and sent to, eNB it detects the existence of collision and sends based RAR with collision flag to MTCD. If collision flag is included, then a probability value is computed using number of contending MTCDs.

**Paper 14**

**Title –** An authentication scheme with identity-based cryptography for M2M security in cyber-physical systems

**Concept –**

In this paper, the author proposes an authentication scheme applying authenticated identity-based cryptography without key-escrow mechanism. In the proposed scheme, only partial secrets instead of full secrets are stored in the MSP, which could prevent the compromised MSP from endangering the whole system. The security analysis with Burrows–Abadi–Needham logic (BAN Logic) and Simple Promela Interpreter (SPIN) shows that the proposed scheme is well designed and could withstand Man-in-the-Middle attacks, impersonation attacks, replay attacks, DoS attacks, and compromised attacks.

**Limitations**

- Signature generation consumes a lot of time and resources
- Large scale implementation is not supportable

**Paper 15**

**Title -** Authentication of IoT Device and IoT Server Using Secure Vaults

**Concept -**In this paper, the author proposed a multi-key (or multi-password) based mutual authentication mechanism. In our approach, the shared secret between the IoT server and the IoT device is called secure vault, which is a collection of equal sized keys. Initial contents of the secure vault are shared between the server and the IoT device and contents of the secure vault change after every successful communication session. Single password-based authentication mechanisms, which are widely used, are vulnerable to side-channel and dictionary attacks.

**Limitations**

- Easily affected by impersonation attack
- Generation of too many keys will increase the computation complexity

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