Context Centric Cluster Computing in Ad Hoc Network (C^4)

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***Abstract*—Cluster computing in ad hoc network draws special attention from the research community due to its inherent support for group communication in varied application domains like emergency and rescue operations, etc. Context sensitive aware cluster computing yields maximum benefits and advantages than the traditional computing. The Cluster Head (CH) and the Cluster Members (CM) effectively coordinate the cluster communication through robust key and trust management. The key management is a crucial and resource demanding phase that has to be effectively monitored by CH. Several factors necessitate the mobility of CM across clusters like node leaving/joining the parent/foreign clusters, the corrupted CH forbidding its current CM to join a foreign cluster. The compromise of CM and periodic key refreshment/update are the other factors that incite the rekeying mechanism needed to preserve the integrity and credibility of the cluster communication. The rekeying kinematics has to be maintained at a low profile to overcome the storage, communication and computational overhead associated with it. The Drifted Existing Cluster Member (DECM) rejoining/re-affiliating to the cluster to which it was previously associated exempts strict divorce/separation from the existing cluster unless it is appended to Node Corruption List (NCL). This process of DECM rejoining the parent cluster demands partial rekeying mechanism enabled through context mining for better resource optimization. The CH maintains collective key instance scenarios/contexts that are rendered to Rejoined DECM (RDECM) for ensuring minimal rekeying rate to preserve forward and backward secrecy. The rejoined DECM after stiff authentication and authorization check by CH seamlessly synchronizes with the cluster through its self-learning ability of cluster contextual mining (CCM) to get introduced to the recently added CM and re-establishing the point of contact with its old neighbors. This process paves way for relaxing the constraints on maintaining stiff forward and backward secrecy in cluster/group computing. This approach precludes the RDECM from having complete history of the cluster to which it reassociates by acquiring glimpse of the several scenarios/context captured by CH. This re-affiliation/reunion entailing minimum change overhead has to be propagated to other CH that treats the new node as its good old Samaritan incumbent node. Various graphs are simulated to adjudge the performance escalation in cluster computing through adoption of this novel technique.**

Keywords*—clustercomputing; MANET; context mining; rekeying mechanism

I. Introduction

A Mobile Ad-hoc Network (MANET) is a self-configuring network of mobile devices that are interconnected by shared wireless links without the aid of any established infrastructure. In a MANET, each device is willing to serve as a router and share its transmission power with other devices because it is required to forward traffic that is irrelevant to its own interest. The nodes entering or leaving the network have routing capabilities which allow them to create multi hop paths connecting node which are not within radio range [1]. The characteristics of MANETs like no fixed network infrastructure, dynamic network configuration, mobility of nodes and frequent node failure, low battery power, etc differentiate them from other wireless networks. MANET have a variety of both civilian and military applications, ranging from emergency disaster relief personnel coordinating rescue efforts after a hurricane, earthquake or brush fire to soldiers exchanging information for situational awareness on the battlefield. Other possible applications include mobile healthcare system, real-time traffic alert propagation via vehicular networks, and Cyber-Physical System (CPS).

Ad hoc network which inherently supports the formation of cluster promotes group communication offering distributed replication of packets as demanded by the number of receivers in the clusters. Clusters with elected Cluster Head and Cluster Member vouch to offer a coordinated secure group communication in ad hoc network. Electing and selecting genuine cluster head is an uphill task complemented by various CH election algorithms. Formation of clusters in ad hoc network eases the bandwidth constraint imposed by the traversing packets through automated delegation of packet transmission to the intended destination/CM by the efficient CH. This process is achieved through well-built key pool comprising CH's Local and global group key and CM's public and private key deployed safely for group communication. The possibility of CM joining/leaving the cluster necessitates stiff rekeying mechanism for ensuring forward and backward secrecy. The dynamic nature of ad hoc network mandates a frequent topology change whereby the nodes joining and leaving the clusters becomes a regular phenomenon entailing storage, communication and computation overhead in the cluster communication. This work recommends the partial rekeying mechanism demanding lesser consumption of network/cluster resources than a complete rekeying mechanism by deploying Context Centric Cluster Computing (C^4). Re-associable cluster members (RCM) are the nodes that do not permanently part with the cluster. The increased node/cluster member mobility should not be a deterrent to robust cluster computing by inciting frequent rekeying mechanism. CH should adopt contextual mining where it facilitates the recording of different snapshots of the key exchange instance and the context that led to it. CH on sensing the rejoin of RCM with the cluster analyzes/mines the key exchange context that had the participation of this node/CM earlier. The cluster computing reverts back to this snapshot that has common CM in these two scenarios alleviating the need for a complete rekey mechanism. This mechanism surely reduces the network burden on computing and storage need and induces performance in an upscale mode.

II. CLUSTER FORMATION IN AD HOC NETWORK

The process of dividing the network into interconnected substructures is called clustering and the interconnected substructures are called clusters. The cluster head (CH) of each cluster act as a coordinator within the substructure. Each CH acts as a temporary base station within its zone or cluster. It also communicates with other CHs. The Cluster based routing provides an answer to address nodes heterogeneity, and to limit the amount of routing information that propagates inside the network. Clustering is one of the techniques used to manage data exchange amongst interacting nodes. Each group of nodes has one or more elected Cluster head(s), where all Cluster heads are interconnected for forming a communication backbone to transmit data. Moreover, Cluster heads should be capable of sustaining communication with limited energy sources for longer period of time. Misbehaving nodes and cluster heads can drain energy rapidly and reduce the total life span of the network.

Clustering in Mobile Ad Hoc Networks (MANETs) has many advantages as routing efficiency, transmission management, information collection compared to the traditional networks. But the highly dynamic and unstable nature of MANETs makes it difficult for the cluster based routing protocols to divide a mobile network into clusters and determination of cluster heads for each cluster. The clustering technique adopts any one of the following clustering approaches like Location based, Neighbor based, Power Based, Artificial Intelligence Based, Mobility based and Weight Based. Each approach advocates its own formation of clusters and cluster head selection for the smooth transit of messages across clusters. A hierarchical routing is possible by clustering in which paths are recorded between clusters instead of between nodes. It increases the routes lifetime, thus decreasing the amount of routing control overhead. The cluster head coordinates the cluster activities inside the cluster. The ordinary nodes in cluster have direct access only to cluster head and gateways. Gateway nodes are those that are present in the overlapping zone of two clusters to facilitate the data transmission across clusters.

Cluster computing in ad hoc network evince special attention from the research community as little effort is directed towards the realization/manifestation of secure trustable computing/routing within the peer MANET nodes. The cluster head acting as a group arbitrator/coordinator for diverse group activities ought to win the confidence of other group members and other voted/elected cluster heads for its continued sustenance. The onus of authenticating the genuine, trustable group member within the group rests with CH. The selection of trustworthy network partners/nodes in cluster based computing promotes hassle free and fair routing within the cluster. Cluster based computing optimizes the usage of network resources and protocol implementation by equalizing the bandwidth for one receiver to multiple receivers in a cluster.

III. CONTEXT AWARE CLUSTER COMPUTING IN AD HOC NETWORK

Cluster members and head extends a seamless cooperation with each other to promote trustable environment facilitating fault free routing and communication with less key exchange between them. Addressing the hard core issues associated with Key exchange planning between the cluster members and with cluster head, distribution pattern, storage and management significantly accommodates improved routing efficiency, efficient neighbor/cluster member discovery and maintenance of sustained relationship between them. Each cluster member is defined as a system entity in MANETs that is capable of observing the behaviors of other cluster members within its radio transmission range, exchanging these observations with other nodes within its radio transmission range, and also sensing the context such as weather condition, battery status, CPU cycles, memory cycles, bandwidth and the motion speed would surely serve as performance booster. The neighbor of a node A is defined as a node that resides within A's radio transmission range.

Table 1: Notations Used

Notation/Symbol	Meaning
CHI & CH2	Cluster head 1 and 2
A^+, A^-	Public, private key pair of each cluster member
LGK^1	Local Group Key for cluster 1
G^2K^1	Global Group key for cluster 1
LGK^2	Local Group Key for cluster 2
G^2K^2	Global Group key for cluster 2
m	Message to be sent across cluster members present in different clusters.

Context aware cluster computing in ad hoc network has profound implications on optimized route discovery enabling cluster formation with minimal key exchange complexity and maintenance. The Cluster head for the clusters with more RCM demands the deployment of contextual mining recommending less complex key exchange mechanism and trivial key pool maintained by each CM and CH. The phase of introducing the new CM with the other CMs demands an extensive rekeying mechanism that ensures forward secrecy to sustain secure cluster communication. This work proposes minimal rekeying rate in face of RCM joining the parent cluster except disclosing the refreshed key for future communication enforcing forward and backward secrecy.

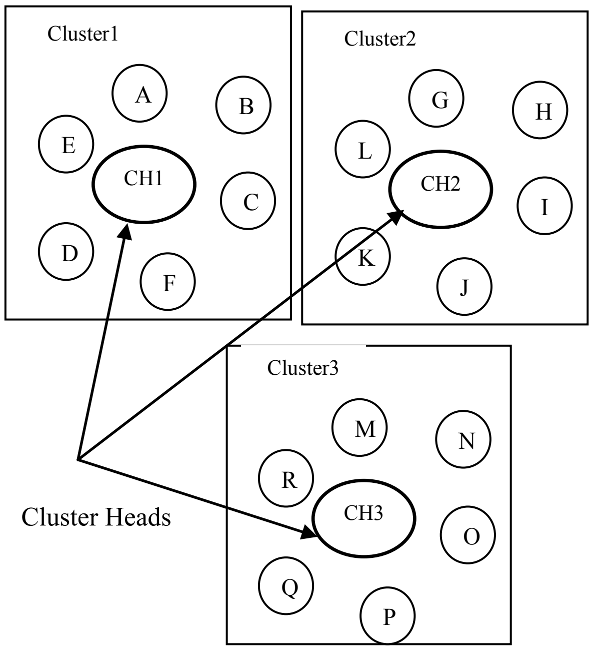

Fig 1. Cluster Formation in Ad hoc Network

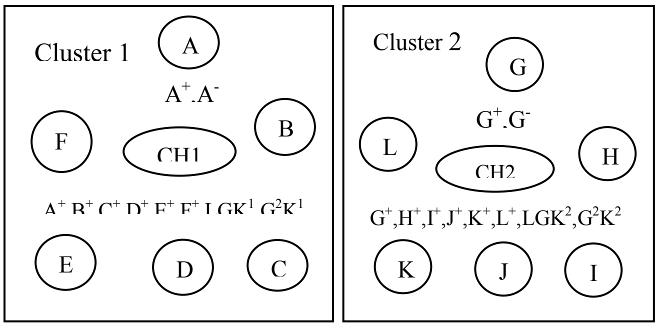

Fig 2. Initial cluster Setup

Figure 3 shows the initial cluster with RCM. Figure 4 depicts the transient scenario where the RCM members have drifted away from the parent clusters. Figure 5showcases the clusters with rejoined RCM with no key exchange and propagation despite passing the updated configuration to the current and new members.

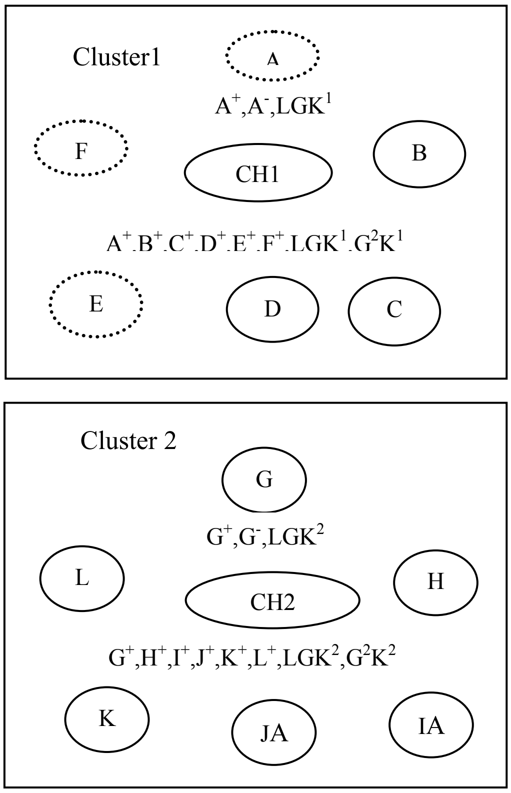

Fig 3. Cluster with RCM

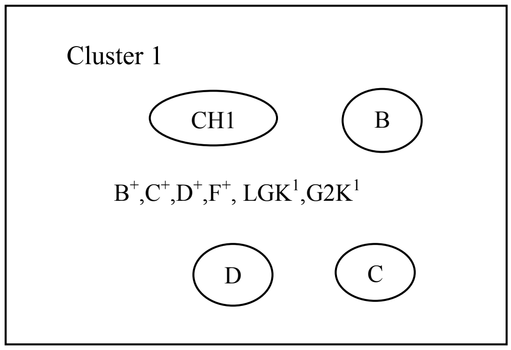

Fig 4. RCM Away from Cluster

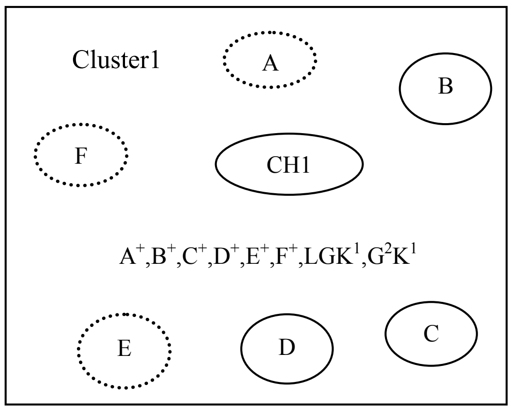

Fig. 5. Reversion back to Original Cluster with Rejoined RCM with Minimal Key Exchange

The RCM in ad hoc network enjoys the provision of joining and leaving the network at its discretionary will/power. This necessitates the frequent key reconfiguration in the network to ensure forward and backward secrecy. The excessive rekeying mechanism squanders the network resources to a greater extent and disappoints the network from performing any productive communication. This work recommends the capture of various snapshots of the cluster with and without the RCM in cluster head. The unification/transient drifting of RCM with the cluster advocates the juggling between the various snapshots through contextual mining of the cluster instance overriding the otherwise costly Frequent Rekeying Mechanism (FRM) between CH and CM. FRM dampens the overwhelming performance of the cluster by expanding its resources for the trivial/futile key exchange which should otherwise have been used for fruitful data exchange.

The revived snapshot with RCM is communicated to the other present nodes/incumbent CM through Diffie Hellmen exchange mechanism. Fair trade off is reached between rekey propagation latency time and quantum of sensible data exchanged among the cluster members. This C^4 mechanism surely aims at improving the cluster throughput by focusing on the usable data exchange than the rekey/control exchange culminating to deterioration in cluster reconfiguration cost and better bandwidth and link utilization. This approach is more suitable to MANET embracing dynamic topology triggered by high degree of mobility and hand off mechanism.

IV. PERFORMANCE ANALYSIS OF THE PROPOSED APPROACH

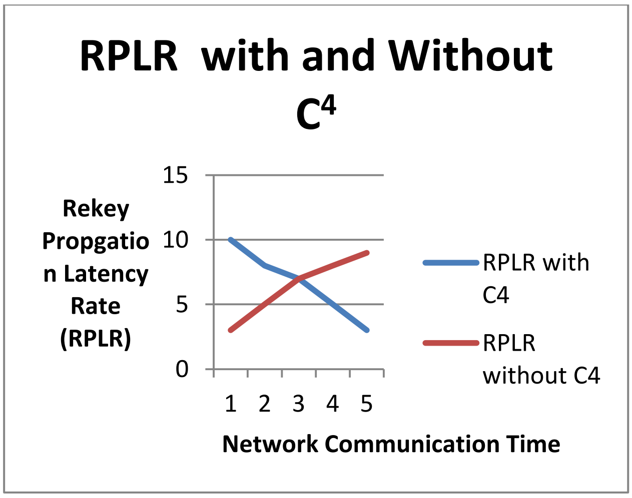

Fig. 6: RPLR in presence and absence of C4

This Self restricted rekeying mechanism is bound to increase the packet throughput with minimal packet delay and jitter witnessing a holistic performance improvement in the network. The effort required for rekey establishment and propagation could be invested for efficient and secure information dissemination across the interested cluster members than incurred for this extraneous activity demanding a heavy share of network resources. The adoption of this approach witnesses a decline in rekey propagation latency time and rate achieved through contextual mining promoting a quick switch over to the required snapshot with less overhead and contingencies. The packet throughput and PDR senses an upscale trend with the adoption of C^4 methodology and vice versa as shown in Fig 6 and Fig. 7.

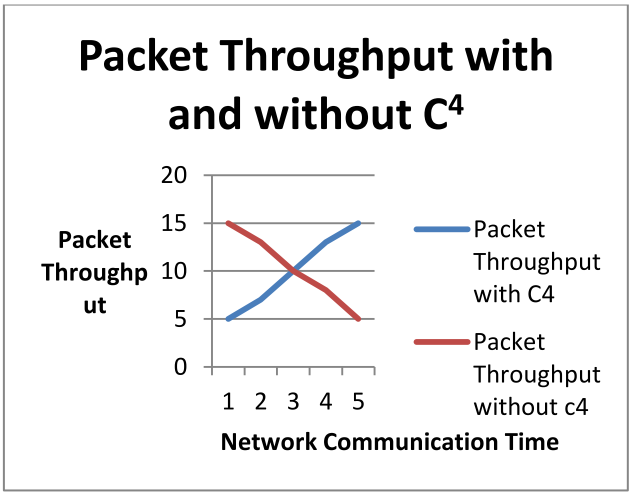

Fig 7: Packet Throughput in presence and absence of C4

V. CONCLUSION

Cluster computing in ad hoc network is gaining increasing acceptance from research community as it inherently supports the formation of group communication. This proposed approach encourages the juggling of diverse cluster communication snapshots/instances through context aware mining in ad hoc network. This method preempts the rekey propagation latency time and rate as necessitated by the consistent drifting/joining nodes to the network ensuring forward and backward secrecy. The context aware mining and mapping promotes a safe and secure communication amidst RCM nodes alleviating the inherent rekeying process associated with every transfer and move of the nodes. The possibility of the nodes getting compromised is precluded had it been enlisted in the trustable nodes list. The CNL comprising RCM leads to deterioration of trust and confidence reposed on it and mandates a strict rekeying mechanism in the event of node join/leave scenario. The performance parameters like Packet throughput and Rekey propagation latency time senses a steep increase with the adoption of this approach.

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