Dynamic Trust Enforcing Pricing Scheme for Sensors-as-a-Service in Sensor-Cloud Infrastructure

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[J1C2 Presentation Abstract at IEEE SERVICES 2021 for IEEE Transactions on Services Computing DOI 10.1109/TSC.2018.2873763]

Sensor-cloud architecture is a wireless sensor network (WSN)-based Service-Oriented Architecture (SOA), in which a Sensor-Cloud Service Provider (SCSP) obtains WSNs on rental basis from multiple sensor-owners and provides these resources to the users in the form of chargeable units of services, termed as *Sensors-as-a-Service* (Se-aaS). A fraction of the revenue earned by the SCSP from the users is distributed among the oligopolistic sensor-owners for the usage of their nodes. Due to the inter-dependency among the sensor-owners for Se-aaS provisioning, selfish sensor-owners behave dishonestly to gain higher profits, thereby degrading the overall QoS. Existing works on sensor-cloud fail to address this issue. Hence, in this work, we propose DETER, a dynamic trust enforcing pricing scheme, which enforces trust among the selfish sensor-owners while ensuring profits for the SCSP.

DETER: The Proposed Pricing Scheme

We consider a sensor-cloud with a few sensor-owners $\mathcal{S}$. Each sensor-owner $s_l \in \mathcal{S}$ owns a set of heterogeneous sensor nodes $\mathcal{O}_l$. The total set of sensor nodes registered with the SCSP is denoted by $\mathcal{N}$. On the other hand, each end-user u_r registers his/her service requirements with the SCSP in terms of the maximum tolerable delay δ and maximum price $\mathcal{P}_{max}$ to be paid based on the *pay-per-use* model. Based on the user requirements, *virtual sensors* are formed by the SCSP for each application j using a subset of physical sensor nodes $\mathcal{N}_j \subseteq \mathcal{N}$. The selected source nodes transmit their sensed data using a multi-hop path to the cloud to serve the user applications.

The proposed scheme DETER is comprised of two parts —

1) Trust Function Calculation: We propose a *bi-level trust factor calculation* method, motivated by the beta reputation model and discounting and consensus operators. We consider dual trust values, defined as the *distributed trust opinion* (DO) and *centralized trust opinion* (CO) sets. In DETER, at time t, each sensor node n calculates the DO set, where $DO^t_{n,i} = (b^t_{n,i}, d^t_{n,i}, u^t_{n,i}, a^t_{n,i})$. $b^t_{n,i}$, $d^t_{n,i}$, $u^t_{n,i}$ and $a^t_{n,i}$ are defined as belief, disbelief, uncertainty, and atomicity, respectively, for its neighbors and $b^t_{n,i} + d^t_{n,i} + u^t_{n,i} = 1$. On the other hand, the SCSP calculates the CO set, i.e., $C^t_n = (b^t_{scsp,n}, d^t_{scsp,n}, u^t_{scsp,n}, a^t_{scsp,n})$, $\forall n$, using the discounting and consensus operators on the CO set C^{t-1}_n, and the opinions collected from the deployed sensor nodes. Here, we have $b^t_{scsp,n} + d^t_{scsp,n} + u^t_{scsp,n} = 1$.

2) Game-Theoretic Dynamic Pricing Scheme: We model the interaction between the SCSP and sensor-owners using a *Single Leader Multiple Follower Stackelberg* game. Here, the SCSP acting as the leader, decides the price to be paid to each sensor-owner while ensuring QoS and maximizing profit, whereas, the sensor-owners acting as the followers, aim to earn high revenue. To select the optimum hop nodes for data transmission, each node n calculates a utility function, $\mathcal{U}^t_{n,i}(\cdot)$, for each neighbor node i. We define $\mathcal{U}^t_{n,i}(\cdot)$ as the net gain of n for choosing i as the next-hop, in terms of the physical characteristics and trust values of i. Thereafter, the SCSP chooses the optimum path based on the utility function, $\mathcal{P}^t_{path_g}$. We define $\mathcal{P}^t_{path_g}$ as the revenue of the SCSP for selecting path $path_g$, while considering its trust value. Mathematically, it can be shown that DETER ensures the existence of Stackelberg Equilibrium, as there exists Nash Equilibrium among the followers.

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Performance Evaluation & Discussion

To evaluate the performance of DETER, we conducted simulations in MATLAB and compared the results with two existing schemes, *dynamic optimal pricing for sensor-cloud* (DOP) [1] and *trust and energy aware routing protocol* (TERP) [2].

Figure 1 shows that the profit of the SCSP increases by at most 50.15% using DETER than by using DOP and TERP. This is because the SCSP does not penalize the selfish sensor owners in DOP or TERP, unlike in DETER. We also observe that, for each service, the average percentage of honest nodes in path improves by at least 0.7-10.04% using DETER than using TERP and DOP. This is because, in TERP, nodes with trust value >0.6 are explored with no restriction on path length, whereas, in DOP, the neighbor closest to the base station is always chosen with no trust value restriction.

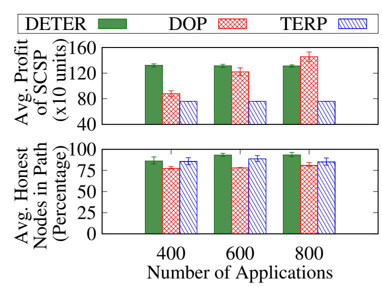

Fig. 1: Results

Thus, DETER outperforms the existing schemes by ensuring trust and high profits of the SCSP simultaneously. This work can be extended to ensure high QoS of Se-aaS provided in the presence of unintentional failures and mobility of sensor nodes.

References

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