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Pagination for Wireless M2M Communications with Encoding and Decoding

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Abstract
Mobile Computing is a term used to demonstrate the technologies that allows people to access network services anywhere, anyplace and anytime. A wireless network is a type of computer network that uses wireless communication networks such as 3G, WIFI, etc., It uses radio waves for establishing connection. In the existing system a mobility based location update scheme is defined to make the location update efficiently and effectively. Based on information theory it is efficient to update the location of the MTC device in the MTC Server only if a new node is added to the parse tree of the MTC device. The Theory of random walks over trees is used to minimize the value of the sum of energy cost and sum of memory cost by optimally pruning the parse tree. The paging mechanism is implemented in order to retrieve the information from the MTC Server.

Keywords
Machine Type Communications, Parse Tree, Wireless Networks, Mobile Management, Paging

I. Introduction

Mobile computing is the domain for building adata management platform, which is free from latitudinal and time-based constraints. This freedom allows its users to access and process desired information from anywhere and anytime in the space. The user may in static or mobile state; it does not affect the information management ability of the mobile platform. The domain of mobile computing has its foundation in Personal Communications Services (PCS). PCS refers to a wide variety of wireless communication and mobility services provided via a small port e.g., cell phone, with the goal of providing communications at required time, at required place, and in any form. M2M Communications provides a future in which the communication and managementof objects in different area. The connection can be established through variety of devices, communications networks and cloud based server. The M2M communications are useful in various fields include smart electric grids, connected cars that react in real time to prevent accidents, and body area networks that track vital signs. M2M communications is a key technology for Internet of Things in which the large number of devices involved in the type leads to a number of research challenges. In 3GPP standards, M2M Communications is also called Machine Type Communications (MTC).

There are many different choices we have to make within the available basic framework, such as how the machine is connected, the type of communication is used, and how the data can be used. Even though it is complex, once a company knows what it tends to do with the data, the decisions for setting up the application are usually straightforward.When it comes to the improved points of machine to machine communication, every choice is unique. The process of M2M communication begins with getting the data from the machine so that it can be evaluated and sent across a network. With an intellectual electronic device, it is possible that it simply connect to the equipment's serial port and request the data needed. The objective of the M2M hardware is to channel the intellect in the machine with the communication network. There are number of good options for transporting the data from the remote equipment to the network operation center.

Data from the machine usually shown in one or two places in the enterprise software application the company uses a standalone system designed especially for M2M communication. The application may be standalone or part of a larger system; the goal is to automate a business process by automating the flow of data to the people and systems that have a need to know. The technology should enable sending the right data to the right place in the right way depending on the environments. It must also present data to the users based on their specific function in the business process. Information theory approaches are used to optimally identify the time instances for the mobile devices to perform location updates. The realizations of information theoretic approaches are based on parsing trees. Parse Trees are the ordered, rooted trees constructed according to one or two computing relations.

II. System Overview

A. System Model

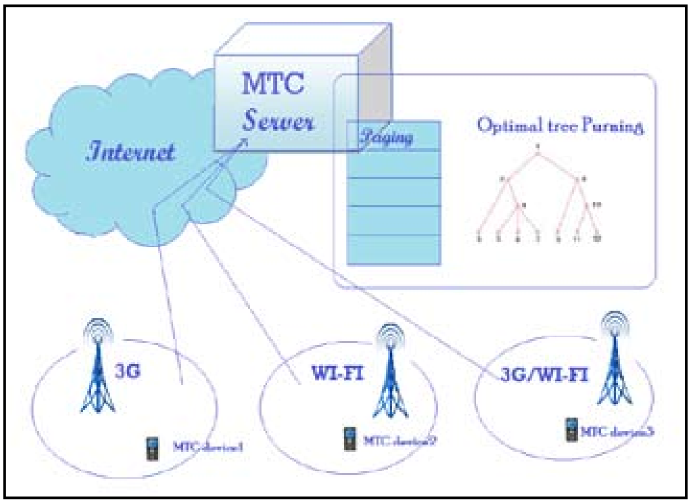

Fig. 1: System Architecture

Figure shows the architecture model of the proposed system. There is a MTC Server and M number of MTC devices which are indexed from 1, 2…., M. The MTC Server is connected to the internet. On the other side MTC device connects to the internet through 3G/LTE wireless networks or with the WIFI access points. The M2M service region is partitioned as α>=2 M2M location areas indexed as 1, 2 ..., α. If the MTC device is equipped with GPS receiver, the M2M location area is equals to the square of width to L meters in earth's surface. If it is not then the device performs sensing within the area covers by the 3G/LTE network. In this paper we consider both the devices with GPS receiver and devices not having GPS receiver. The proposed algorithm can be revised to use it in the device which is not equipped with GPS.

At first we use the continuous-time model for modeling the mobility pattern of the MTC device. Then the discrete-time model is derived from the continuous-time model. Let us take $(x_m(t),y_m(t))$ as the position of mth MTC device at time t, where t is a non-negative real number. It is assumed that for each integer m, where $1\leq m\leq M$, $x_m(t)$ and $y_m(t)$ are continuous and discrete functions. S_{max} be the positive real number is the maximum speed of a MTC device in meters per second. In the previous idle mode mobility management to reduce energy consumption the device performs the location update frequently. Thus the proposed model uses the discrete-time mobility model. The discrete-time model is as follows:

Let T be the positive real number. Time is partitioned into time slots of equal length. The total length of the time slots is equal to T seconds. The kth time slot is defined by the time interval between [(k-1)t, kT], $\forall k\geq 1$. By considering the continuous-time mobility model, for ith MTC device in time slot k+1, where $1\leq i \leq m$ and $k\geq 1$ we have $-S_{max} T\leq x_i((k+1)T-x_i(KT) \leq S_{max} T$ and $-S_{max} T\leq y_i((k+1)T-y_i(KT) \leq S_{max} T$. The index of the M2M location area of the mth MTC device at time kT, $\forall k\geq 1$ is represented by a random variable $X_k^{(m)}$. To identify the value of $X_k^{(m)}$ the MTC device performs sensing.

A Graph G=(V,E) contains V number of vertices and E number of edge set. Which is used to represent the relationship between the index value of the mth MTC device at time k and k+1 i.e.) $X_{k+1}^{(m)}$ and $X_k^{(m)}$. The vertex i is the ith location area of mth device. The edge (i, j) represents the edge from index i to index j. The edge (i, j) ϵ E if and only if the MTC device moves from index i to index j i.e.) $P\{X_{k+1}^{(m)}=j \mid X_k^{(m)}=i\}>0$. For each i ϵ V, it is defined that $N1(i)=\{j \mid (i, j) \epsilon E\}$. Since we already know that the maximum speed of the MTC device in a time slot is S_{max} T and the width of the location area is L, then $\mid N_1(i) \mid \leq 2[S_{max} T/L]+1)^2$. Along with that $\mid N_1(i) \mid \leq \mid V \mid = \alpha$. Hence $\mid N_1(i) \mid \leq \min\{(2[S_{max} T/L]+1)^2,\alpha\}$ which states that if a MTC device is in index i of the M2M location area at time kT then at time (k+1)T the device will be reside in the index j of the M2M location area where j ϵ $N_1(i)$. The total number of edges d(i, j) is the shortest path from vertex i and vertex j.

The Discrete Time Markov Chain (DTMC) is used for modeling the mobility pattern of a device. For each static m, the discrete time stochastic process $\{X_k^{(m)}\}k=o^{\infty}$ is known as the Discrete Time Markov Chain with state space (1, 2, …, α). If $(i,j)\in/E$, $P\{X_{k+1}^{(m)}=j \mid X_k^{(m)}=i\}=0\forall m,k$. The MTC device can be either static or mobile.If the MTC device is static, $P\{X_{k+1}^{(m)}=j \mid X_k^{(m)}=i\}=1$ and $X_k^{(m)}= X_0^{(m)}$ for ∀k.i. If the mth MTC device is mobile, $P\{X_{k+1}^{(m)}=j \mid X_k^{(m)}=i\}<1,\forall i$. we consider the fact $\lim k\rightarrow\infty$ $P\{X_k^{(m)}=j\}$ exists for ∀m,j.

B. Parsing Tree for Information Theory Location Update

Each of the MTC devices will be maintaining a parse tree and a queue. Initially both of this are empty. The number of nodes in the parse tree is limited to γ. Each node in the parsing tree contains an index and a label. The index represents the order in which the node is added to the tree. If i is a node then the index of the node is equal to i. The label L_i represents the M2M location area in which the device located when a node i is added. Each node contains array of α pointers. Each pointer points to the child node or it is a null pointer. The node i has the set Φ_i which contains the indexes of the children nodes.

Initially the parsing tree composed of a root node with index zero and label Ø. The total number of nodes in the parsing tree at time t is represented as N (t). Hence N (t-) be the number of nodes before time t, the index of the newly added node at time t is set to be N (t-). Define $t_k=kT\ \forall\ k\geq 1$. Let us take S_k as the index of the node pointed by the current state pointer before time t_k. Note $S_1=0$. Define $\theta_k=\{Lj:j\in\Phi(S_k)\}$ which represents the labels of the node Sk. At time tkthe value of Xkis inserted into the queue. If the value of $X_k=\theta_k$ the device will not perform any location updates. Now the S_{k+1} is set as largest integer such that j ϵ S_{k+1} and $L_j = X_k$. If $X_k \neq \theta_k$ a new node is added with index $N(t_k\text{-})$and label X_k is added as a child node of S_k and S_{k+1} is set to 0. In addition to that each of the MTC devices will perform encoding on the messages in the queue and clears it. For example if kth node is added to the parsing tree the [log2(α·k)] number of bits are used for encoding the messages. Likewise the MTC device performs the location update and sends the encoded bits to the MTC Server.

The following example is used to illustrate the above notations. Supposeα=4,$X_1=1,X_2=1,X_3=2,X_4=3,X_5=2,X_6=2,X_7=1,X_8=1$and $X_9=1$.Attime t_1, since $S_1 =0,\Phi(S_1)=\varnothing$, $\theta_1 =\varnothing$, and $X_1\in/\theta_1$, node $N(t^-)=1$ is added into the parsing tree as a child of node 0 and S_2 is set to be 0. Inaddition to that based onLZ78data compression algorithm X_1 is encodes into $[\log_2(\alpha\cdot 1)]=2$ bits of 00 since X_1-1=0. After that the MTC device will perform the location update and sends the encoded bits 00 to the MTC Server. The MTC Server receives the first location update information and decodes the bits 00 using the LZ78 data compression algorithm and finds out $X_1=1$. At time t_2 we know $S_2=0,\Phi(S_2)=1$ and $\theta_2=\{1\}$ there will be no new node added into the parse tree and the device will not perform any location update.

Table 1.1 Dictionaries for Encoding Location Update Messages

I	Record creation time	The ith substring	$v_i,w_i,f(i)$ $(s_i=v_i\oplus w_i\ s_{f(i)}=v_i)$	Integer to be encoded for location update $m_i=f(i)\alpha+ w_i-1$	Number of sent bits for location update $[\log_2(\alpha i)]$	Bits sent for location update
0	0	Ø				
1	t_1	$1(X_1)$	Ø,0.1	(0*4)+(1-1)=0	2	00
2	t_3	$12(X_2\oplus X_3)$	1,2,1	(1*4)+(2-1)=5	3	101
3	t_4	$3(X_4)$	Ø,3,0	(0*4)+(3-1)=2	4	0010
4	t_5	$2(X_5)$	Ø,2,0	(0*4)+(2-1)=1	4	0001
5	t_7	$21(X_6\oplus X_7)$	2,1,4	(4*4)+(1-1)=16	5	10000
6	t_9	$11(X_8\oplus X_9)$	1,1,1	(1*4)+(1-1)=4	5	00100

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Table 1.2 Dictionaries for Decoding Location Update Messages

I	Record creation time	Expected number of bits for location update $[\log_2(\alpha i)]$	Received bits for location Update	Received Integer for location update m_i	Quotient q_i of dividing m_i by α	Remainder r_i of dividing m_i by α	s_i the ith substring $s_i=s_{qi}\oplus(r_i+1)$
0	0						
1	t_1	2	00	0	0	0	Ø⊕(0+1)=1
2	t_3	3	101	5	1	1	1⊕(1+1)=12
3	t_4	4	0010	2	0	2	Ø⊕(2+1)=3
4	t_5	4	0001	1	0	1	Ø⊕(1+1)=2
5	t_7	5	10000	16	4	0	2⊕(0+1)=21
6	t_9	5	00100	4	1	0	1⊕(0+1)=11

Since $L_1=X_2$,S_3 is set to be 1.At time t_3, we know $S_3=1,\Phi(S_3)=\varnothing$, $\theta_3=\varnothing$ and $X_3\in/\theta_3$, node $N(t_3-)=2$ will be added in the parsing tree as a child of node 1and S4 is set to 0. Using LZ78 data compression algorithm the string $X_2\oplus X_3=1\oplus 2=12$is encoded into $\log_2(\alpha*2)=3$ bits 101. Then the device performs the location update and sends the three bits 101 to the MTC Server. When the server receives the location update message, it decodes the three bits and concludes that $(X_2, X_3)=(1,2)$

C. Pruning the Parsing Tree- Theory of Random Walks over Trees

The memory size of each MTC device is finite and hence the parsing tree could not grow forever. It is essential to prune the parsing tree of the MTC device. In order to prune the parsing tree, an efficient approach based on the theory of random trees is proposed. The parsing tree is pruned by using this approach in an optimal way to minimize the cost. The memory cost is an increasing function of the total number of notes in the parsing tree and the energy cost is a decreasing function of expected value of the time difference between two consecutive location updates.

Let Γ be the parsing tree to be pruned and there are γ nodes in the parsing tree. Suppose at least one node has to be removed. In order to maintain the structure of the parsing tree if node i is removed and i<j node j also has to be removed. Hence Γ_{-k} is the tree obtained after removing the node with index greater than k from the Γ. Once the tree has been pruned, the current state pointer points to the root node. Let $\Phi_{-k}[i]$ contains the set which composed of the indexes of the children of node i in the Γ_{-k}. From the above we can say that parsing tree Γ pruned to be Γ_{-k}. By using the previous location update history we can easily predict the next location update time. In particular we can derive the discrete-time Markov chain for tree Γ_{-k} as $\{Y_n^{-k}\}_{n=0}^{\infty}$ with state space Ω-k= {-1, 0, 1, 2, .., k}as follows. First,state i oftheDTMCcorrespondstonode i in the tree Γ_{-k},$\forall 0\leq i\leq k$. Inaddition,state−1isan absorption state. In particular $Y_0^{-k}=0$ and $Y_m^{-k}=1$ if and only if the MTC device performs the location update at time tm. The state transition probabilities for the DTMC $\{Y_n^{-k}\}_{n=0}^{\infty}$ depends on the mobility pattern of the MTC device. Let qi be the estimated value of the probability of the MTC device located in the ith M2M location area and $q_{i,j}$ be the j^{th} M2M location area at the next sensing time instance. The state transition probabilities for the DTMC $\{Y_n^{-k}\}_{n=0}^{\infty}$ as follows:

$$P\{Y_{n+1}^{-k}=j|Y_n^{-k}=i\}$$

$$=\begin{cases} q_{\tau,L_j}, \ if\ i=0\ and\ j\in\Phi_{-k}(i) \\ 1-\sum_{j:j\in\Phi_{-k}(i)} q_{\tau,L_j}, \ if\ i=0\ and\ j=-1 \\ q_{L_i,L_j}, \ if\ 1\leq i\leq k\ and\ j\in\Phi_{-k}(i) \\ 1-\sum_{j:j\in\Phi_{-k}(i)} q_{L_i,L_j}, if\ 1\leq i\leq k\ and\ j=-1 \\ 1,\ if\ i=j=-1 \\ 0,\ otherwise. \end{cases}$$

D. Paging Scheme

Concurrently search for a number of mobile users in a wireless cellular network based on the probabilistic information about the locations of mobile users. The concurrent search approach guarantees that all mobile users will be located within time slots. It is shown that even in the worst case when mobile users appear equally in all the cells of the network, the concurrent search approach is able to reduce the average paging cost by 25%. More importantly, this is achieved without an increase in the worst case paging delay or in the worst case paging cost. Depending on the total number of mobile users to be located, total number of cells in the network, and the probabilistic information about the locations of mobile users, the reduction of the average aging cost due to the usage of the concurrent search approach ranges from 25% to 88%.

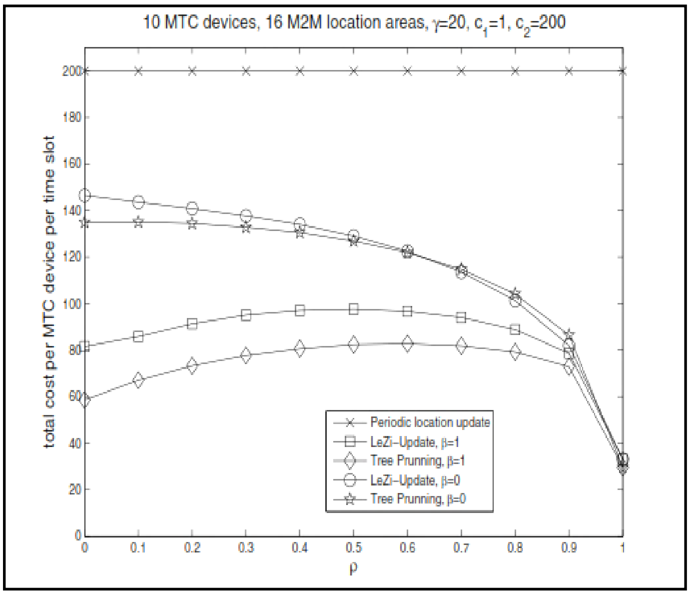
E. Decentralization of Server

The MTC devices may grow with population. Hence there is a chance for MTC server will get overloaded. It leads to the decrease in server performance. Therefore the MTC server's job is decentralized and it increases efficiency.

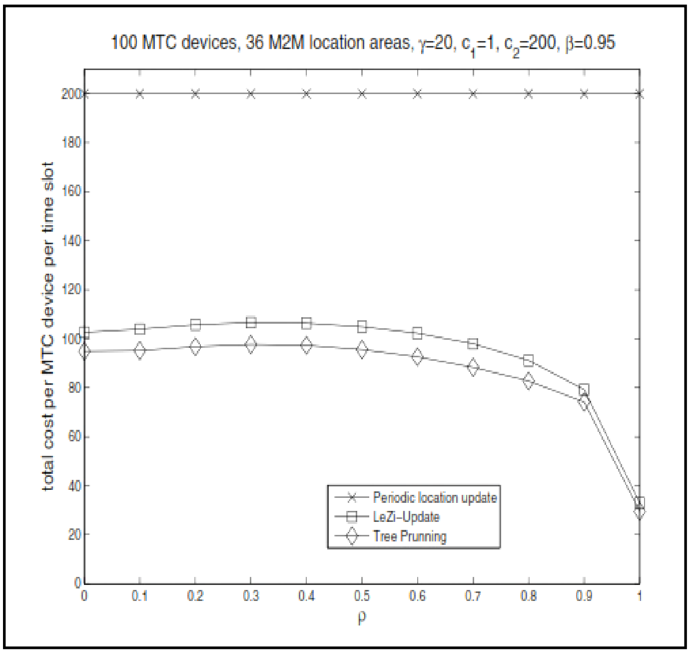
III. Analytical Results

Let us consider a MTC device and Vn be the random variable that represents the nth time where the parsing tree contains γ nodes, ∀n≥1. We first prove that V_1 is finite. It states that from the time instances when the current state pointer points to the root node to the time instance when the node is added into the parsing tree, each the already added node is pointed by the current state pointer in at most one sensing period.Therefore it will take at most k sensing periods for the number of nodes to increase from k to k+1.

IV. Simulated Results



3.1 The total cost of location update scheme, when there are 10 MTC devices



3.2 The total cost of location update scheme, when there are 100 MTC devices

V. Conclusion

We have found that the proposed scheme could significantly reduce the location update cost. Future works include jointly optimizing the location update scheme and the paging scheme for wireless M2M communications. Another direction of future research is to explore and exploit the statistical correlations among the movements of MTC devices for mobility management. Utilizing cloud computing technologies for large-scale implementation of the decoding part of the proposed location update algorithm is a promising direction of future research.

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