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Application of Vehicle Routing Model to Mobile-Health Cloud Management in South Africa

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ABSTRACT

Emergence of Mobile technology and Cloud computing have brought rapid development in the globe especially in the health sector. In South Africa, the use of mobile-health cloud has greatly improved the healthcare system by reducing less hospitalization of patients and also provides appropriate intervention of the right medical personnel. Though, it has played some positive impacts especially when it involves prescription of medicine to patients' remotely. However, mobile health services in several rural communities in South Africa are still facing some challenges when it requires physical consultation by few medical experts. One of this is on how to determine the optimum route that will minimise the distance covered to these communities. This is because going through the wrong route may increase the distance thereby taking more time to get to the destination. In addition, it will also cost more. This work proposes the use of vehicle routine model to determine the optimum route in mobile-health cloud management in South Africa. A model is formulated using KwaZulu Natal province and the Lazy Branch and Bound Algorithm is applied as the solution approach to determine optimal route. The application of this model which invariably reduces cost and patient's overall waiting time is the contribution of this work. Implementation of this is done using Mathematical 9.0. The results obtained provide the optimum route and the cost associated per distance shows that the model is cost effective and time saving.

Keyword –Mobile Health, Cloud computing, Branch and Bound, Patient.

1. INTRODUCTION

Cloud computing is an information technology service model that allows computing services to be provided on-demand to customers over a network in a self-service fashion and independent of devices and location. These services include Software, Infrastructure and a Platform [1]. With this technology, cloud providers and consumers can interact without necessarily comings into contact. It uses the Internet to invoke services that are delivered in the cloud through various machines such as mainframe computers, desktop computers, laptops and various digital systems. With rapid growth in mobile technology both in low- and middle-income countries, particularly in Africa and in the less affluent and rural communities, mobile device access is far greater than access to computers in developing countries. For instance, in South Africa about 50 million people have mobile phone access and everyday experience confirms a near-universal mobile ownership, with everyone from street vendors to top-level executives carrying one [2]

The emergence of the cloud technology allows mobile services to be integrated with cloud services. This is achieved by allowing the processing data and storage to move from the mobile device to powerful and centralized computing platforms. This is then accessed over the wireless connection based on a thin native client or web browser on the mobile devices [3]. For instance, in South Africa about 50 million people have mobile phone access and everyday experience confirms a near-universal mobile ownership, with everyone from street vendors to top-level executives carrying one [4]. This integration which is called Mobile Cloud Computing (MCC) has provided various advantages. These include but not limited to: ease of integration, multi-tenancy. In addition, integrating this with other devices like sensors has made it to be useful in the other context. For example: m-health, e-learning and e-banking.

Under the m-health, most developing countries have adopted the mobile technology as the solution approach to health care delivery system. For example in South Africa which is leading the way in mobile health in Africa [4], the availability of low-cost mobile phones and the already broad coverage of GSM networks is a huge opportunity to provide services that would trigger development and improve people's lives. So many applications have been developed in South Africa in the area of m-health. For example the Dokita 247[5], the e-HealthConsult [6] that allows clinicians to connect to and communicate with colleagues and specialists anywhere in South Africa. Also the work designed by the division of Telemedicine and m-Health at the Medical Research Council. This allows workstations to facilitate telemedicine in South Africa, by making basic components such as computers, cameras and reliable internet connectivity more available in the public sector. In addition is the FolUp [7].

The basic objectives of these applications are to monitor patients' health, diagnose and if possible:

i. Prescribes medicine to the patients remotely.
ii. If need be especially patients with chronic diseases, have a physical consultation with patients in those communities by the few medical experts.

The first one requires communication between medical experts and patients through wireless communication. That of the second requires the few medical experts on ground to cover some distances. This will invariable incur costs based on the distance covered. Most researchers have concentrated on the first one [8],[9] while little or less attention is on the second one. On the second issue, determination of optimum route to cover by the medical experts that will minimize distance covered to these communities is a challenge. This research proposes the use of vehicle routine model to determine the optimum route in mobile -health cloud management in South Africa. A model is formulated in the context Mobile Health Cloud Management (MHCM) using KwaZulu Natal province.

This work to the best our knowledge is yet to appear in the context of MHCM in South Africa. The remainder of this paper is organized as follows. Section II discuss the related work. Section III introduces our model description. The experimental results are laid out and discussed in Section IV. We have the conclusion in Section IV.

2. LITERATURE REVIEW

Developing application to solve health related issues started more than 100 years ago [10]. The recent advances in mobile communications have also impacted m-Health systems positively especially in South Africa. For example, the Dokita 247 [11][5]. This system involves the use of SMS & cell phone technology for information management, transactional exchange & personal communication. In [12], the authors investigate the integration of IoT and MCC. This is achieved through the designing of DropLock architecture dedicated to Smart City. This uses mobile devices, sensors and Cloud computing. Two things the paper achieved: It presents the cutting edge convergence between IoT and MCC. The second is that of allowing researchers to understand the benefits of the integration. The work in [13] designed and implemented a mobile remote health monitoring system (MRHMS) based on wireless technologies. It uses sensors for monitoring patients' bio-signals like blood pressure and breathing. This is connected to the supervisor's agent and the mobile base unit through Bluetooth technology. These are then connected to hospital site through GPRS and Internet technology.

The major importance of this work is that real time medical attention could be given and where necessary physical consultation is done. In [14], the authors uses data structure using age, smoking habits and alcohol intake to simulate the blood pressure, the pulse rate and the mean arterial pressure of patients. This is done by encrypting the simulated data using the symmetric key encryption Algorithm to generate a secret key used for the encryption. On the performance of m-health, the work in [15] proposes a realistic simulation environment for healthcare system. This uses vital signs model, wireless sensor and mesh network protocols for the implementation. The believe of the author is that, the factor affecting reliability of transmission of information in any network is as a result of congestion. In [16], The researchers evaluated the performance of m-health system in South Africa under a non-preemptive priority and non-priority discipline. The theory was based on queuing theory and Discrete Event Simulator is used to demonstrate real live scenario.

The result reveals that the unconditional average waiting time remains the same with reduction in waiting time over the non- preemptive priority model in four out of the five classes observed. Some Scholars [8],[9] propose the use of inbuilt applications on smart phones for health service management. Other scholars [17],[18] propose the idea of using wearable sensors as the means of sending patients' medical information to the few available medical experts. On the work of [19], the authors developed a Real-Time Health Monitoring System for Remote Cardiac Patients using Smartphone and Wearable Sensors. This is done by creating patient interface that comprises of wearable sensors. This is then used to extract medical information of the patients and transmit to an Android based listening port via Bluetooth, The patient information is then transferred to the web server that processes the data to show reports on doctor interface. We appreciate the work of these authors for their contributions to the existing body of Knowledge. However, the shortfalls observed give us the chance to make our contribution.

For example, most of these works are centered on development of M-health system [14][11][5][8][9]. Also, few concentrated on the performance[17][18] using different parameters. For example, issues of reliability and waiting time. In general, these works concentrated on the M-health management from the perspective of performance and remote treatment of patients. Little is done in that of management of available resources when the treatment involves physical consultation to patients by medical experts to communities especially patients with chronic diseases. Our work is differentiated from these works in that:

- It is cantered on the optimization of the route covered by few medical experts when physical consultations are required.
- The use of Vehicle routine model as a solution approach in the context of MCHM to determine the optimum route that will minimise the shortest distance which invariably reduces cost and overall waiting time.

These to the best of our know ledge are yet to appear in the literature in the context of MCHM in South Africa.

3. THE ANALYTICAL MODEL DESCRIPTION

The model consists of the general architecture and the sub architecture real one that is the crux of our work. On the general, it consists of various mobile health users from KwaZulu Natal province. For example, Stanger and Watburg as shown in Fig. 1. These patients are with various wearable equipment (sensors) serving as the sensing organ. When the equipment observes certain misbehavior in the body of patients, messages are transferred to the cloud heath server via base station. The Cloud server processes the data collected from the patients and transfer the information to medical experts in GreyTown medical hospital. This GreyTown hospital is assumed to be in charge of various communities like Stanger, Watburg and others as shown in Fig 1and 2 respectively.

This information is studied by these experts and if this is a minor problem that just requires prescription, then a message is sent back to the patient. If however, it requires these medical experts to physical consultations with patients in various communities, then the health unit will then need to how many experts are on ground (N). In addition It will also know the number of various communities that require services and the distance to GreyTown. This is depicted in Fig 2.

The crux of this work is the determination of the optimum route that will minimise the shortest distance. To achieve this we define

i. GreyTown as the Deport (D)
ii. Medical Expert as ME

and we assume the followings:

i. That we have a given number (N) of medical experts in GreyTown (Deport). Where N = 1,2,3,......

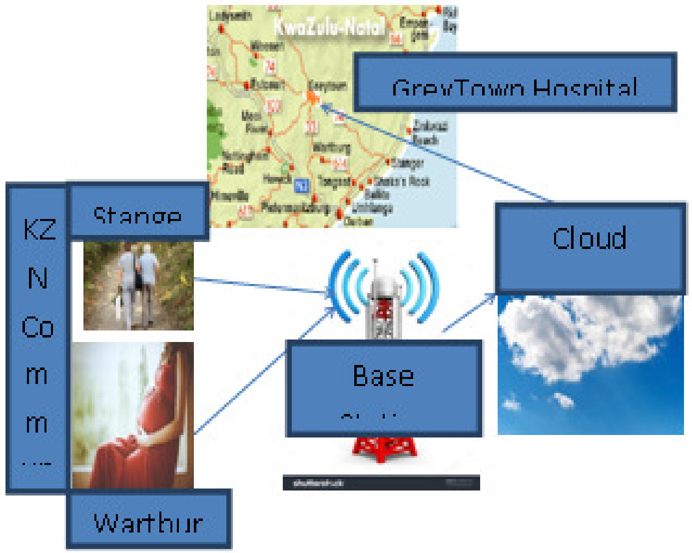

Figure 1: General Architecture of the System

To use the Vehicle routine model, we first allocate city numbers to various cities. This is shown in Table 1. Then Fig. 1 is then presented using the numbers with the available numbers of medical experts (N). In this experiment we assume our N to be 4. The symmetric matrix table of 10 by 10 is displayed with 6 cities (1-6), 4 medical experts (7-10) and the distance from city I to J(X_{ij}). For example the distance from city 1 t0 city 2 is given as 220 while that from city 2 to city 3 is given as 320. But one cannot move from the same city to the same city. This is represented as “-“ in the table.

Table 1: City Allocation from GreyTown

City	No
Escourt	1
Weenen	2
Mool River	3
Stanger	4
Tongaat	5
Wartburg	6

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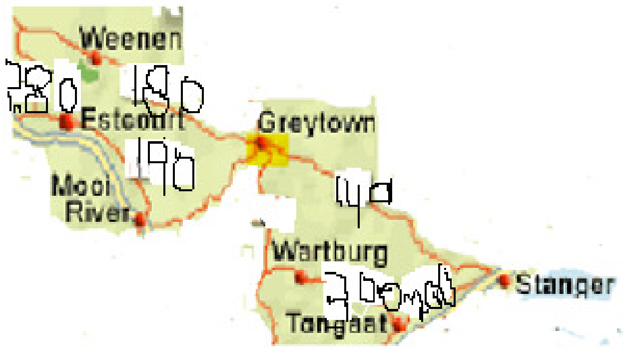

Fig. 2: GreyTown City and other Communities with distances

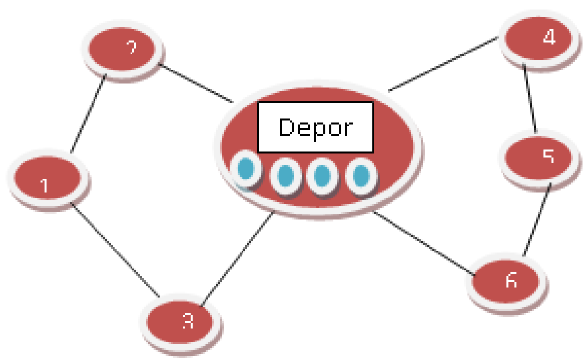

Fig. 3: Deport -Location Map

Table 2: Distance- City-Medical Expert (ME) from Deport

c	1	–	220	180	300	260	280	200	200	200	200
		220	–	320	200	220	210	180	180	180	180
i	2	180	320	–	200	220	210	140	140	140	140
		300	200	200	–	300	220	160	160	160	160
t	3	260	220	220	300	–	260	120	120	120	120
;		280	210	210	220	260	–	190	190	190	190
M	4	200	180	140	160	120	190	–	–	–	–
		200	180	140	160	120	190	–	–	–	–
E	5	200	180	140	160	120	190	–	–	–	–
		200	180	140	160	120	190	–	–	–	–

The use of "-" under the ME in the table represents ∞ meaning that all the four medical experts will be used for the physical consultation. We use the Branch and Bound (B&B) Algorithm to solve this problem. This involves some components as stated in [20]. These are:

- a bounding function: This provides from a solution space the subspace that has a Lower Bound(LB) for the best solution value obtained in that subspace,
- a strategy for selecting the live solution subspace to be investigated in the current iteration, and
- a branching rule to be applied if a subspace after investigation cannot be discarded, hereby subdividing the subspace considered into two or more subspaces to be investigated in subsequent iterations.

Apart from this, fathoming of nodes can be facilitated to get initial good feasible solution using heuristic approach however, If no such heuristic exists, the initial value of the incumbent is set to infinity. We applied the B&B Algorithm described in [20] using the Lazy Branch and Bound mechanism where g is the bounding function . This is shown in Table 2.

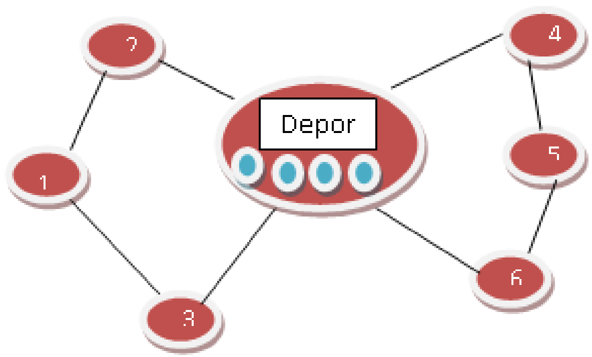

Figure 4: Proposed Optimal route for the four Medical Experts

Table 3: Lazy Branch and Bound Algorithm

```
Initialize: Incumbent := -∞; Live := {(P0, −∞)}
 Repeat until Live = ∅ Select the node P from
Live to be processed; Live := Live \ {P};
 Bound P: LB(P) := g(P)
     If LB(P) = f(X) for a feasible solution X
       and f(X) < Incumbent
    then
        Incumbent := f(X);
        Solution := X;
        go to EndBound;
        If LB(P) ≥ Incumbent
        then
           fathom P
        else
          Branch on P generating P1, ...Pk;
         For 1 ≤ i ≤ k do
           Live := Live ∪ {(Pi, LB(P))};
         EndBound;

 OptimalSolution := Solution; OptimumValue
:= Incumbent;
```

4. RESULT AND DISCUSSION

To get our result, we used the aforementioned Algorithm with the use Mathematical 9.0. This is like searching through a tree. The idea is that the root node corresponds to the original problem. If for example we have a node Q as the original problem, then the children are the sub problems derived from Q by putting a new constraint. This then gives room for many descendants of Q with leaves. Each node in the tree has a bound (real number) through the use of bounding function *g*. This *g* must satisfy these three conditions:

- $g(Pi) \leq f(Pi)$ for all nodes *Pi* in the tree
- $g(Pi) = f(Pi)$ for all leaves in the tree
- $g(Pi) \geq g(Pj)$ if *Pj* is the father of *Pi*

The leaves correspond to feasible solutions. In this experiment we have many numbers of leaves which we show some in Table 3. For example, G-1-2-G -3-4-G-5-G-6-G. The selection Algorithm selects the most feasible among the feasible one. The iteration continues until the optimal solution is derived. The optimal route that produces the minimum distance covered by the four medical experts is depicted in Figure 4. Thi is in the form of G-2-1-3-G-4-G-5-G-6-G, it shows that:

i. Medical Expert 1 will cover from Deport (GreyTonw) to city 2 (Weenen), from city 2 to city 1(Escourt) and from city 1 to city 3(Mool River) and return.
ii. Medical Expert 2 will cover city 4 (Stanger) and return.
iii. Medical Expert 3 will cover city 5 (Tongaat) and return and
iv. Medical Expert 4 will cover city 6 (Wartburg) and return

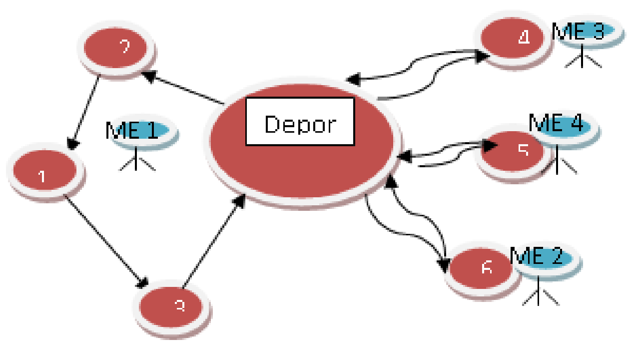

Figure 5: Proposed Optimal route for the four Medical Experts

It is concluded that G-2-1-3-G-4-G-5-G-6-G is the optimal route for the travelling salesman delivering to appointed addresses. Duration of the route is 6500 meters,

That 180+220+180+140+160+160+120+120+190+190.

This is depicted in Figure 4. In Table ... we calculated the distance of some other routes and attached R100.00 per distance covered. The one with the minimum cost per distance is that of optimal root which is G-2-1-3-G-4-G-5-G-6-G. That implies that the model is cost effective. Also, we allotted 2 hrs. as the time required to cover 1 kilometer. From the Table the one with the minimum distance per hr. is the one with optimal route highlighted. This also implies that the overall waiting time is reduced.

Table 4: Some feasible routes

Route	Distance (Km)	Cost/Distance	Distance/hr
G-2-1-3-G-4-G-5-G-6-G	1660	R166000.00	3320
G-1-2-G -3-4-G-5-G-6-G	1720	R17200.00	3440
G-2-G -1 -4-G-5-G-6-3-G	1780	R17800.00	3560
G-1-G-4-G-3-5-G-2-6-G	1780	R1780.00	3560

5. CONCLUSION

Two things can happen after diagnosing patients under M- Cloud Health Management in South Africa. The first is either to prescribes medicine to the patients remotely and the second is to have a physical consultation with patients in those communities by medical experts especially patients with chronic diseases. Most literature has delved into the first while little attention has been drawn to the second issue. Minimization of cost and patient waiting time depend on how the distance covered by the available experts can be minimized when physical consultations are required. The focus of this research is to determine the optimum route that will minimise the distance covered to these communities in South Africa. To tackle this, we propose the use of vehicle routine model as the solution approach. Some communities in South Africa are used from KwaZulu Natal province. A distance – medical expert model is formulated and the Lazy Branch and Bound Algorithm is applied. The result obtained after some iterations provide the optimal route which invariable reduces cost and the overall patients waiting time.

While this model has provided the optimal route, it may be difficult to apply in an environment where the numbers of cities or communities are large. Other model could be proposed.

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