Performance Analysis of Offloading Systems in Mobile Wireless Environments

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Abstract- Offloading is an approach to leverage the severity of resource constrained nature of mobile devices (such as PDAs, mobile phones) by migrating part of the computation of applications to some nearby resource-rich surrogates (e.g., desktop PCs, mobility support stations). It is an essential mechanism for the execution of pervasive services. However, the mobile nature of mobile devices and the unstable connectivity of wireless links all render a less predictability of the performance of a pervasive service running under the control of offloading systems. This paper proposes an analytical model to express the performance of offloading systems in mobile wireless environments. We investigate the surrogate unreachable when mobile devices move following random waypoint (RWP) mobility scheme. We model the failure recovery time and total execution time of pervasive applications that run under the control of offloading systems. Detailed evaluation and analysis results are reported and the results of this paper can be used as design guidance for pervasive service offloading systems.

Keywords: Modeling, Performance analysis, Offloading System, Mobile Wireless Environment

I. INTRODUCTION

Recent years have seen a significant increase in research and development of wireless LANs and mobile networks. With advances in mobile terminals and wireless communications, the demand for mobile devices to run heavier applications (like which are running on desktop PCs) is on increase. Apparently even the most powerful PDAs today (due to the size and weight constraints) are unable to compete against their desktop siblings with regard to any type of resource, and especially battery life and network capacity. Meanwhile, in some of the working and living environment, the computing resources are often rich. For instance, in offices or cafes, some desktop PCs may be idle while the mobile devices are busy. As such it makes sense for these resource-constrained mobile devices to make use of the resources available in their vicinity to leverage its resource insufficiency. For example, George on his mobile could well rely on the base station (or his PDA relying on a nearby desktop PC) to carry out computation-intensive decoding so as to play back the fabulous performance of his favorite football team in a nimble and cost-effective manner. He might even instruct his mobile support station (termed surrogate) to download the champion clips in advance through the surrogate’s broadband network resource. We refer to this kind of computation or communication migration as offloading for pervasive services [2]. It is also called surrogate computing or cyber foraging [1].

Much research work on offloading systems under wireless environment has been carried out [1-4]. However the majority of them focus only on architectural or algorithm aspects of offloading. There is still a lack of systematic means to evaluate the performance of offloading systems that takes into consideration the uncertainty of wireless mobile environments. While on the other hands, the offloading system developers and providers would like to know how effective and efficient their offloading systems are and what factors influence the performance of their offloading systems. The similar concerns are also from the potential users of the offloading systems.

There are several researches on performance modelling and analysis of the mobile computing and the underlying wireless environments [8, 11, 12]. Qu et al. proposed a model to evaluate the performance of mobile agent systems [12]. Chen et al. proposed a performance analysis model for mobile applications in wireless environments [11]. However, these models do not consider users’ mobility and only simply model the failures as Poisson processes with specified parameters. As an improvement, Fang proposed a model to relax the exponential assumptions for the involved time variables in wireless mobile networks [8]. In our model, the failures, specifically, the surrogate’s unreachable are approximated by the RWP (Random Waypoint) mobility model.

Inspired by the above work and driven by the increasing need of such an analytical model for performance analysis, this paper investigates specifically the performance of offloading systems under wireless mobile environments. In our previous work [2], some preliminary performance analyses have been carried out, mainly experimentally, in terms of the speedup ratio of the offloading mechanism to the application execution time. However, these analyses are specific for the offloading systems concerned and not a generic approach that is applicable also to other offloading platforms. Furthermore, the performance analysis was carried out with assumption of error-free wireless environments, namely the potential faults of the systems (such as link breakage due to increased interference or node mobility) have not been taken into consideration. In this paper, performance evaluation is carried out in terms of surrogate unreachable, failure recovery time and execution time over error-prone mobile wireless environments. The analysis results can provide useful guidance to the design of efficient offloading systems.

The remainder of this paper is organized as follows. Section II presents some preliminaries for performance analysis of offloading systems in mobile wireless environments. A performance model is described in detail in Section III. Evaluation and performance analysis are reported in Section IV. The paper concludes in Section V.
II. PRELIMINARIES

A. Offloading Systems in Mobile Wireless Environments

Fig. 1 shows an example of offloading systems in mobile wireless environments. A mobile host (MH) and a surrogate are located in an area. Though a surrogate can be movable, we only consider in this paper stationary surrogates which is the common case. The MH may move in the area during the application’s offloading execution. When a surrogate is available (i.e., the MH is in the radio coverage of the surrogate), the offloading system will adaptively offload part of its computation from the MH to the surrogate. An application running in an offloading system is consisted of components (such as Java/C++ classes). An offloading system firstly loads all the components in, and then instruments them on-the-fly to make them suitable for remote execution. According to local resource availability and network conditions, all the components will then be adaptively partitioned into a local execution partition for running locally and one for more remote execution partitions for running on surrogates.

Refer to our previous work [2] for detailed description on the offloading mechanism, such as application instrumenting, application partitioning, offloading strategies and offloading execution.

For modelling simplicity, the offloading system to be modelled and analyzed in this paper carries the following assumptions. However, some of these assumption can be relaxed by updating the model – refer to Section III-E for discussion on this.

- The mobile wireless network environment considered is a wireless ad hoc local area network where MH’s connect to a surrogate in a one-hop manner.
- Surrogates are uniformly distributed in a given area tested.
- Offloading events, triggered by an offloading decision making engine [2], are assumed to follow a Poisson process.
- A MH can offload computation to only one surrogate, namely, multiple surrogates for one single application-level task are not supported simultaneously.
- The handoff time between two surrogates in overlapped areas is very small and as such ignored
- During offloading execution, a disconnection between a MH and a surrogate is treated as a failure.

B. Mobility Model and Surrogate Unreachability

Since the mobile wireless network environment is considered to be a wireless ad hoc local area network, the MH moves around in such a network environment and it connects to surrogates in an ad hoc manner. We employ the most commonly used mobility model, random waypoint (RWP) mobility scheme [7], to model the MH’s movement.

The most significant effect of MH’s mobility on offloading systems is the availability of surrogates and the quality of the wireless links between the MH and surrogates. Though the link quality is affected by some complex factors, such as mobility, noise and interference, fading, and so forth, we focus only on mobility, the non-physical-layer factor. We investigate the unreachability of surrogates, i.e., the probability of the location of the moving MH being out of all the surrogates’ radio transmission ranges, and most importantly the impact of this probability on the performance of offloading systems and on the overall strategic decision making when carrying out offloading.

In this work, we consider the commonly used one-dimensional mobile ad hoc network environment in which the MH and surrogates are located on a line. However, the principles are equally applicable to two-dimensional ad hoc network environments [6]. Let $X$, a continuous random variable, be the MH’s location coordinate. We assume that the MH chooses at random a speed $v_i \in [V_{\text{min}}, V_{\text{max}}]$. The approximation of the location is proposed by [6] and is given as follow: The asymptotically stationary probability density function (p.d.f.) of the location $X$ of the MH moving on a line $[0, d]$ according to the RWP model without pause and $V_{\text{max}} > 0$ are accurately approximated by

$$f_X(x) = \frac{6}{d^3} x^2 + \frac{6}{d^2} x, 0 < x < d$$ (1)

Let a constant $D$ be the surrogate’s radio transmission radius. Let $x_s$ and $x_M$ be the location of a surrogate and the MH respectively. The surrogate is unreachable if $x_M - x_s > D$. Since the surrogates’ locations are fixed and known, their radio coverage (including overlapped areas) can be obtained. Let $m$ be the number of surrogates. The line $[0, d]$ is separated into $m + 1$ sub-segments, $\{[0, x_s^1 - D), (x_s^1 + D, x_s^2 - D), \ldots, (x_s^m + D, d]\}$, which are out of the radio coverage. Let $Y$, a random variable, which be the MH’s location coordinates which are out of surrogates’ radio range. Since the surrogates are stationary, based on equation (1), the probability of surrogate un-reachable (i.e., the MH is out of coverage.
When an offloading event occurs, an offloading event instant therefore is:

\[
\alpha = \int_{x_{m+1}}^{x_{m+2}} f_x(x) \, dx + \sum_{i=1}^{m} \int_{x_{i+1}}^{x_{i+2}} f_x(x) \, dx + \int_{x_{m+1}}^{x_{m+2}} f_x(x) \, dx \tag{2}
\]

for \(m > 0\); If \(m=0\), \(\alpha=1\), i.e., there is no surrogate in the line. Fig. 2 shows an example of two surrogates located at \(d/3\) and \(2d/3\) respectively. Except for the two shadowed areas, the sum of the areas under the parabola is the probability of surrogate unreachable.

Since the surrogates’ locations are known, \(\alpha\) is a constant. Let \(P\) be a random variable denoting the time to the first epoch that the surrogate(s) are unreachable. Since the probabilities of surrogate unreachable in each sampling time are considered to be independent and same, i.e. \(\alpha\), the events of surrogate unreachable can be modelled as a Poisson process and the random variable \(P\) follows an exponential distribution with parameter \(\alpha\) [9]. Thus, the p.d.f. of \(P\) is:

\[
f_p(p) = \alpha e^{-\alpha p}, \quad p \geq 0 .
\]

III. PERFORMANCE MODEL OF OFFLOADING SYSTEMS

A. Offloading System Modeling

There are four states when an application runs with the support of an offloading system as depicted in Fig.3: non-offloading execution (\(S_{NE}\)), offloading (\(S_{OL}\)), offloading execution (\(S_{OEL}\)), and failure and recovery (\(S_{FR}\)). During an application’s execution, two events are of particular interest to the performance analysis of an offloading system: offloading event and failure event.

As assumed, offloading events follow a Poisson process with rate \(\beta\). When an offloading event occurs, an offloading time \(M\) will be taken for migrating components and related data. When a failure occurs, a period of time \(R\) for recovery will be taken. \(M\) and \(R\) are modelled as random variables with general distributions.

A failure occurring during an application execution period immediately interrupts the execution. When the failure is recovered, an execution period of the same duration as the one interrupted begins again from scratch. The execution is completed when an execution period elapses without failure. Failures can occur during the \(S_{OL}\) and \(S_{OEL}\) states due to surrogate being unreachable when the MH is moving. A disconnection between the MH and a surrogate is treated as a failure. Failures can also occur during the \(S_{FR}\) state. In this case, the failure recovery aborts and has to begin again from scratch. Adapting fault-tolerant mechanisms can save some time spent for re-execution. However, discussions on fault-tolerant offloading systems are beyond the scope of this paper.

As the surrogate unreachable is considered as the only cause of failures in the states \(S_{OL}\), \(S_{OEL}\) and \(S_{FR}\), \(\alpha\) becomes the probability of failures in our model. Because the state \(S_{OE}\) is not affected by wireless environment, the failure occurrences during this state can be ignored. We assume that failures are detected as soon as they occur and after the application is recovered, it comes back to the non-offloading execution state, \(S_{NE}\). The application terminates when the execution of all the sub-tasks are finished.

B. Application Execution Time without Failures

Let \(n\) denote the number of sub-tasks constituting the application. The sub-tasks finish randomly according to a Poisson process with rate \(\lambda\). Let \(T(n)\) denotes the application’s execution time with the required sub-task number \(n\). Without considering the time spent on offloading operations and failure recoveries, an application’s pure execution time in an offloading system can be expressed as

\[
T(n) = T(\alpha) + T_{[1-\sigma]n},
\]

where \(\sigma\) is the proportion of sub-tasks performed by the surrogate. \(T_{[\alpha]}\) and \(T_{[1-\sigma]}\) denote the time spent in the surrogate and the MH for performing the \(n\) sub-tasks. We assume \(\sigma = \alpha C\), where \(C\) is a constant. A speedup factor \(\omega = \frac{T_{[\alpha]} + T_{[1-\sigma]}n}{T(n)}\) is defined to represent a surrogate’s execution speed comparing with the MH’s execution speed. If \(\omega = 1\), the execution speed of the surrogate and the MH are same. Normally, \(\omega\) is larger than \(1\) due to surrogates are resource-rich and more powerful. Thus, we have

\[
T_{[\alpha]} = \sigma T(n) + (1-\sigma)T(n) = \left(1 - \frac{(\omega-1)\sigma}{\omega}\right)T(n)
\]

where \(T(n)\) is the application execution time in the MH without the presence of offloading and failure recoveries.

With the presence of offloading and failures, the application execution time increases due to failure recoveries and the application needs to be re-executed from scratch. We use \(T'(n)\) to denote the total execution time in such case and it will be discussed in detail in Section III-D.

C. Failure Recovery Time

The failure recovery time is a period used by the offloading system to re-execute the application from the scratch to the failure point after a failure. Once an application enters state \(S_{FR}\), the time period \(R\) is required to complete a recovery task. By using an efficient approach which is similar to [10] and [11], we evaluate the failure-recovery time as follows.

Let \(R'\) be the failure recovery time in the presence of failures within the recovery period \(R\). Let \(P\) be the time to the first failure after starting recovery, then we have

\[
R' = \begin{cases} 
R & \text{if } P > R \\
 R + \hat{R}' & \text{if } P \leq R 
\end{cases}
\]

where \(\hat{R}'\) denotes the additional recovery time for the repetitive failure. If \(P > R\), then a recovery will be successfully completed without nested failures during the
recovery period. If \( P \leq R \), a nested failure occurs. In this case, a new recovery operation is repeated after \( P \), so the recovery time is \( P + R \).

The c.d.f. of the random variable \( R \) is \( F_R(t) \). Taking the Laplace Transform of \( F_R(t) \), we have
\[ L_R(s) = \int_0^\infty e^{-st} F_R(t) dt = E(e^{-sR}). \] (5)

Thus, the problem of calculating \( R \) is simplified to the problem of calculating \( E(e^{-sR}) \). Taking conditional expectation on \( R \) and \( P \), we have
\[ E(e^{-sR} \mid R, P) = \begin{cases} e^{-sP} & \text{if } P > R \\ e^{-sP} E(e^{-sR}) & \text{if } P \leq R \end{cases} \]

Since \( P \) is independent of \( R \), if the condition on \( P \) is removed, we get
\[ E(e^{-sR} \mid R) = \int_0^\infty E(e^{-sR} \mid R, P = p) f_P(p) dp \]
Based on the definition of \( f(P) \) in equation (3) and (2), we simplify above equation as:
\[ E(e^{-sR}) = \int_0^P e^{-sP} E(e^{-sR}) \alpha e^{-\alpha y} dp + \int_P^\infty e^{-sR} \alpha e^{-\alpha y} dp = \alpha E(e^{-sR}) \left( 1 - e^{-(\alpha+y)R} \right) + e^{-\alpha y} \]

According to equation (5), further un-conditioning on \( R \) yields
\[ L_R(s) = \frac{\alpha L_R(s) \left( 1 - L_R(\alpha + s) \right)}{\alpha + s} + L_R(\alpha + s) \]

Rearranging, we have
\[ L_R(s) = \frac{(\alpha + s) L_R(\alpha + s)}{\alpha L_R(\alpha + s) + s} = \alpha E(e^{-\alpha R}) + s \]
Applying the moment generating property of the Laplace transform, the expectation of \( R \) is
\[ E(R) = \frac{d L_R(s)}{ds} \bigg|_{s=0} = \frac{1}{\alpha} \left( \frac{1}{\alpha} - 1 \right) = \frac{1}{\alpha} \left( \frac{1}{e^{\alpha R}} - 1 \right) \] (7)

D. Execution Time with Failures

Based on the assumptions made in Section II-A and the offloading system model defined in Section III-A, the random variable \( T(n) \) inherits an Erlang distribution with parameter \( \lambda \) \[9\]. Let \( h, h=1,2,3,\ldots, \) be the number of transitions from \( S_{j-1} \) to \( S_{j} \) or \( S_{j+1} \), i.e., the number of offloading during an application’s execution. Thus, the total execution time becomes \( T(n) + \sum_{i} u_i \). Let \( P \) be the time to the first failure event after starting program execution. Considering both the cases of offloading and the failure recovery, we get the total application execution time \( T^+(n) \) by
\[ T^+(n) = \begin{cases} T(n) + \sum_{i} h M_i, & \text{if } P \geq T(n) + \sum_{i} h M_i \\ P + R^+ + \tilde{T}^+(n), & \text{if } P < T(n) + \sum_{i} h M_i \end{cases} \]
(8)

If \( P \geq T(n) + \sum_{i} h M_i \), the program will make \( h \) offloading operations before it finishes \( n \) sub-tasks without failures. In this case, the total offloading time is \( \sum_{i} h M_i \) and the total components execution time is \( T(n) + \sum_{i} h M_i \). The offloading times \( t_i, i=1,2,\ldots,h \) are independent and identically distributed random variables. If \( P < T(n) + \sum_{i} h M_i \), a failure occurs before the program finishes \( n \) sub-tasks and makes \( h \) offloading operations. In this case, there is a recovery time \( R^+ \) after which the component execution is restarted from its beginning, which means that the component is required to re-execute \( n \) sub-tasks without failure interruptions again. Following the similar steps in the analysis of Section III-C, we have
\[ L_{T^+(n)} = \frac{(\alpha + s)(\lambda + \alpha + s - \beta E(e^{\alpha R}))}{\alpha} \] (9)
and the expectation of the application’s execution time is
\[ E(T^+(n)) = \left( \frac{\alpha + s}{\alpha} \right) \left( \frac{1}{(\lambda + \alpha + \beta - \beta E(e^{\alpha R}))} \right) \] (10)

E. Discussion on Assumption Relaxation

The above performance model can be adapted to less constrained wireless network environments. Some guidance discussions are presented below.

1) Relaxing the one-hop assumption to multi-hop real-life case: Via multi-hop relaying, a MH can offload its tasks to surrogates that are multiple hops away. In this case, the radio transmission radius of the relay nodes (either mobile or stationary) will be treated as surrogate’s coverage area. Thus, the surrogate unreachability, \( \alpha \) (refer to equation (2)), will become smaller. Multi-hop relay will affect some network-layer parameters, such as delay, time-to-live (TTL), and so forth.

2) Relaxed Surrogate distribution from uniform distribution to non-uniform distribution: If surrogates are not uniformly distributed on a line \([0, d]\), the probability of the unreachability of a surrogate might not follow an exponential distribution. According to the property of surrogate unreachability (refer to Section II-B), if node movement follows RWP scheme, placing more surrogates in the central of the line can reduce the surrogate unreachability. Refer to Section IV-A for detailed explanation of surrogate distribution.

3) Considering disconnection tolerance: In the above discussion, disconnection between a requesting MH and a serving surrogate is simply treated as a failure of task execution. This assumption can be relaxed by introducing certain fault-tolerant technique, such as checkpointing mechanism [13]. In the latter case, after the connection is recovered, the application can carry on execution from the latest checkpoint rather than from the very beginning.

With the presence of fault-tolerance mechanism, the total application execution time \( T^+(n) \) becomes
\[ T^+(n) = \begin{cases} T(n) + \sum_{i} h M_i, & \text{if } P \geq T(n) + \sum_{i} h M_i \\ P + Q + R^+ + \tilde{T}^+(n'), & \text{if } P < T(n) + \sum_{i} h M_i \end{cases} \]
(11)
It is same as equation (8), if \( P \geq T(n) + \sum_{i} h M_i \). However, if \( P < T(n) + \sum_{i} h M_i \) (i.e., a failure occurs before the program finishes \( n \) sub-tasks and makes \( h \) offloading operations), the finished sub-tasks do not need to be re-executed again. The \( Q \) in the equation is the duration of the disconnection. After the connection is recovered, following a recovery time \( R^+ \), the unfinished \( n' \) sub-tasks will continue to execute. Obviously, in
IV. NUMERICAL RESULTS AND ANALYSIS

A. Surrogate Unreachability

We simulate a one-dimensional environment with the length of 900 meters (refer to Fig. 2). There are \( m \) \((m=0,1,…,15)\) surrogates distributed according to the following schemes: uniformly distributed (scheme 1), mainly distributed in the central area (scheme 2), and mainly distributed in the border areas (scheme 3). The radio range \( D \) is set as 30 meters. The surrogate unreachabilities are calculated by using equation (2) and shown in Fig. 4.

In the figure, three different distribution schemes result in different features of \( \alpha \) distribution. The curves clearly show the border effect of the RWP \([6]\); that is, the MH tends to cross the centre area with a relatively high frequency. The uniform distribution, scheme 1, has a nearly linearity decreasing curve when the number of surrogates increasing. However, the curve is slightly deflexed due to the border effect; that is, linearly increased number of surrogates in the border areas can not reduce \( \alpha \) very much. In scheme 2, surrogates are apt to distribute in the centre area. Along with the increase of the number of surrogate, \( \alpha \) is getting smaller than scheme 1 due to more surrogates distributed in the centre area. Contrarily, scheme 3 has the highest \( \alpha \) values due to surrogates are mainly distributed in border areas. In scheme 1, 15 surrogates can make a full coverage, i.e. \( \alpha = 0 \); however, for the non-uniform distributions, such as scheme 2 and 3, there are still some areas without coverage, i.e. \( \alpha > 0 \).

B. Application Execution Time

We analyse the application execution time affected by different surrogate unreachabilities with following parameters: \( \omega = 2 \), \( \sigma = 0.5 \), \( E(M) = 10 \), \( E(R) = 8 \), \( \beta = 0.4 \), \( \lambda = 0.01 \), \( C = 1 \). We compare the execution time ratio which is \( \frac{T^\prime[\omega] + T^\prime[\sigma]}{\omega} \) under different \( \sigma \) values.

Fig. 5 depicts the results. The three curves increase exponentially and with almost same shapes. It is clear that the execution time ratios increase sharply when the number of sub-tasks increasing. When \( \alpha \) getting bigger, e.g., \( \alpha > 0.2 \), the application execution time becomes unacceptable.

C. Efficiency of Offloading Systems

We have discussed three kinds of application execution time in Section III. They are: i) \( T^\prime(n) \) - the application executes in the MH without the presence of offloading and failure recovery; ii) \( T_{\text{no fail}}(n) \) - the application executes in ideal offloading systems without failures; iii) \( T^\prime(n)/\omega \) - the application executes with the presence of offloading and failure recoveries. In the third case, if a failure occurs, the application needs to re-start from scratch. Considering an enhanced offloading execution strategy, only the sub-tasks executing by the surrogate need to be re-executed when a failure occurs. Thus, we have the fourth case of application execution time:

\[
T^*(n) = T^\prime[\omega] + T^\prime[\sigma] / \omega
\]  

(12)

where \( T^\prime[\omega] \) is the time spent on the MH and \( T^\prime[\sigma] \) is spent on the surrogate. \( T^\prime[\sigma] \) can be calculated using the same approach as the third case. Note that the fourth case and the disconnection operation are different and we will compare them specifically in Section IV-D.

We compare these four cases under different speedup factor with following parameters: \( n = 200 \), \( \sigma = 0.6 \), \( E(M) = 5 \), \( E(R) = 4 \), \( \alpha = 10^3 \), \( \beta = 0.4 \), \( \lambda = 10^2 \), \( C = 1 \). We assume the average execution time for each sub-task in the MH is 3 seconds. Fig. 6 shows the results. The Case 1 is a horizontal line at 600s. In the Case 2, the ideal case, the execution time decreases along with the increasing of speedup factor. The Case 3 produces a very long execution time when \( \omega < 7 \) due to offloading and failure recoveries; it has the same execution time as Case 1 when \( \omega = 7.2 \) and the execution time decreases afterwards. The enhanced offloading execution strategy, Case 4, has a same execution time as the Case 1 when \( \omega = 2.5 \) and the execution time in this case decreases along with the speedup factor increasing with the same shape of the Case 2.

The results are illustrated in Fig. 6 also reflect the factors affecting the efficiency of offloading systems. With larger speedup factor, the surrogate can save execution time in the
MH. However, the time spent on offloading operation and failure handling will increase the total execution time. Especially, in higher surrogate unreachability environments, or surrogates are less-powerful, (i.e., with small speedup factor), offloading may not able to reduce the total application execution time.

D. Disconnection Operation and the Case 4

We have mentioned that the Case 4 is different with the disconnection operation in Section IV-C. In the Case 4, when a failure occurs, the MH does not wait for the connection recovery; it re-executes the sub-tasks (which are offloaded to the disconnected surrogate) by itself or by another available surrogate. Whereas, in the disconnection operation case (refer to Section III-E), the MH waits for the connection be recovered and the sub-tasks in the surrogate do not need to be re-executed.

Using the same setting as that used in Section IV-C, we compare the Case 4 with the disconnection operation. We assume the temporary disconnection occurs after the surrogate executed half of the offloaded sub-tasks and the disconnection duration $Q$ is set as 4, 8 and 12 seconds, respectively. Fig. 7 shows the comparison. It can be seen that the disconnection operation gets smaller execution time when $Q$ is small, (e.g. $Q=4s$). However, the Case 4 is better when $Q$ is getting bigger.

V. CONCLUSION

In this work, we proposed an analytical model for performance analysis of offloading systems operating in mobile wireless environments. By adapting the most commonly used random waypoint scheme as the mobility model of MHs, the surrogate unreachability has been modeled. The failure recovery time, the application execution time and the execution efficiency are modeled and evaluated. The analysis results indicate the following high-level design guidelines for offloading systems: i) in the higher surrogate coverage areas, offloading systems can speed up the application execution time; ii) the surrogates’ distribution severely affect the surrogate unreachability in wireless ad hoc networks; iii) in the environments with higher surrogate unreachabilities or smaller speedup factors, offloading will not benefit to reduce application execution time; iv) if the duration of disconnection getting longer, allowing disconnection operation will increase the application execution time.

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