Offloading of 3G Traffic to WiFi with Trade-off between WiFi Utilization and Service Outage

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Abstract

With explosive increase of data traffic in 3G networks, offloading to WiFi is widely employed. While switching to WiFi as soon as it is available maximizes WiFi utiliztion and hence minimizes 3G usage, average number of service outages(connected to neither WiFi nor 3G) will also increase. Previous research considers only the SNR of closest WiFi AP to switch or not to WiFi with some hysterisis to prevent pingpong syndrome. We propose a scheme which provides control knobs for trade-off bewteen WiFi utilization and service outage.

For this we estimate the disconnection (moving out of WiFi area without 3G connection) probability using the relative distance from WiFi AP, MN(Mobile Node)'s step size assuming random movement for simplicity. We introduce two thresholds, P_{IN} and P_{OUT}, to control the switching behavior of an MN. If MN enters WiFi coverage and the disconnection probability is less than P_{IN}, MN switches to WiFi. If MN is near the boundary of WiFi coverage and the disconnection probability is higher than P_{OUT} then we switch to 3G to prevent possible disconnection on its next move. If we increase P_{IN} and P_{OUT}, then WiFi utilization is higher with higher average number of service outages. If we decrease P_{IN} and P_{OUT}, then WiFi utilization is lower with lower average number of service outage. We present our scheme in pseudo code and illustatres it with some example simuations. It is easy to expand our scheme for more realistic situtations considering moving patterns of MNs and etc.

Our contribution is to provide simple control knobs for WiFi offloading to trade-off between WiFi utilization and average number of service outages experienced by users.

Keywords: offloading, disconnection probability, handover

1 Introduction

With explosive increase of data traffic in 3G networks, offloading to WiFi is widely employed. To improve offloading efficiency, mobile node (MN) needs to only perform handover at the AP coverage border but the probability MN will suffer disconnection becomes high.

In a conventional scheme [1], the goodput measured for 3G and WiFi are compared and if an improvement of the goodput is expected in case of change of network the handover is executed. The goodput is calculated based on the bandwidth allocated to the MN and service outage probability. They mainly focus only on maximizing performance in terms of throughput, and does not address trade-off between offloading efficiency and user QoS.

In this paper, we propose a scheme which provide simple control knobs for WiFi offloading decision to trade-off between WiFi utilization and average number of service outages experienced by users

2 Proposed Scheme to Trade-off WiFi Utilization vs Service Outage

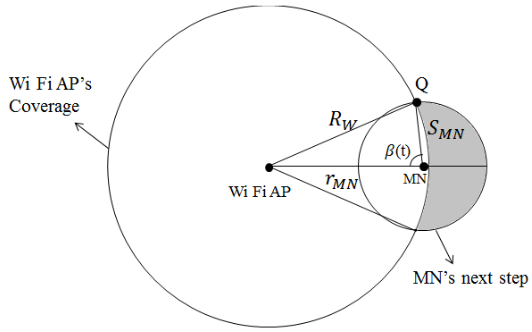

Figure 1. Estimation of disconnection probability

Table 1. parameters for proposed scheme

input	Description
R_W	Radius of WiFi coverage
r_{MN}(t)	Distance from the nearest WiFi AP at t
$S_{MN}\angle$RAN(θ)	Step movent of MN with random orientation
P_{IN}	The threshold for initiaing WiFi connection
P_{OUT}	The threshold for initiaing 3G connection

output	Description
β(t)	An inner angle of the triangle formed by WiFi AP, MN and Q
ST_{MN} (t)	Current state of MN at t 'WiFi', '3G', 'None'
p_D(t)	The probability that MN moves out of WiFi coverage on the next step at time t . $p_D(t) = (\frac{\pi - \beta(t)}{\pi})$ in Fig 1

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When MN moves around it encounters WiFi area covered by a WiFi AP. If MN switches to WiFi as soon as it is available, we may maximize WiFi utilization. However the probability MN suffers disconnection is high on its next movement or vice versa. We provide a scheme to trade-off the WiFi utilization vs service outage under simplified conditions. Figure 1 illustrates our approach. For simple explanation, let's assume MN moves with a fixed unit step, S_{MN}, with random orientation. R_W represents the radius of coverage of a closest WiFi AP. If MN is near the boundary of circle formed by R_W as in Figure 1, we draw a circle of radius S_{MN} centered at MN. This circle represents all the possible locations of the MN at the next step. Out of this perimeter, the arc enclosing shadowed region represents possible disconnection on the next step if MN does not switch to 3G at current position. The disconnection probability clearly depends on the current loaction of MN and can be estimated as in Figure 1. Equations (1) through (4) shows how disconnection probability P_D(t) is obtained.

$$S = \frac{R_W + r_{MN}(t) + S_{MN}}{2} \tag{1}$$

$$\eta(t) = \sqrt{\frac{1}{S} \cdot (S - R_W) \cdot (S - r_{MN}(t)) \cdot (S - S_{MN})} \tag{2}$$

$$\cot \frac{\beta(t)}{2} = \frac{S - R_W}{\eta(t)} \tag{3}$$

$$p_D(t) = \frac{\pi - \beta(t)}{\pi} \cdot 100(\%) \tag{4}$$

We introduce two parameters, P_{IN} and P_{OUT} to control the offloading behavior of an MN. If MN enters WiFi coverage and $P_D(t) < P_{IN}$, MN switches to WiFi. If MN is near the boundary of WiFi coverage and $P_D(t) > P_{OUT}$, then we switch to 3G to prevent disconnection. If we increase P_{IN} and increase P_{OUT}, then WiFi utilization is high with high disconnection probability. If we decrease P_{IN} and decrease P_{OUT}, then WiFi utilization is low with low disconnection probability. Table 1 summarizes the parameters used in our scheme and the pseudo code in Algorithm 1 represents a simplified version of our scheme. Table 2 illustrates our trade-off scheme with P_{IN} = 10% and variable P_{OUT}. For example if P_{IN} = 10%, P_{OUT} = 20%, the WiFi Utilization is 64.2% with average number of disconnections per minute is 3.4 assuming MN moves at intervals of a second.

Algorithm 1 MN handover process

Initialization
Case I : ST_{MN} (t) == '3G'
IF (r_{MN} (t) $\leq R_W - S_{MN}$) ||
  ($R_W - S_{MN} < r_{MN}$ (t) $\leq R_W$ && P_D (t) $< P_{IN}$) **THEN**
  ST_{MN} (t+1) = 'WiFi'
  GOTO JUMP;
ELSE
  ST_{MN} (t+1)= '3G'
END IF
Case II: ST_{MN} (t) == 'WiFi'
IF r_{MN} (t) $> R_W$ || ($R_W - S_{MN} \leq r_{MN}$ (t) $\leq R_W$
  && $P_{OUT} < P_D$ (t)) **THEN**
  ST_{MN} (t+1) = '3G'
ELSE
  ST_{MN} (t+1) = 'WiFi'
  GOTO JUMP;
END IF
Case III: ST_{MN} (t) == 'None'
GOTO JUMP;
IF ($R_W - S_{MN} < r_{MN}$ (t+1) $\leq R_W$ && P_D (t) $> P_{IN}$) ||
  r_{MN} (t+1)$> R_W$ **THEN**
  ST_{MN} (t+1) = '3G'
ELSE IF ($R_W - S_{MN} < r_{MN}$ (t+1) $\leq R_W$ &&
  $P_{OUT} > P_D$ (t)) || r_{MN} (t+1)$< R_W - S_{MN}$ **THEN**
  ST_{MN} (t+1) = 'WiFi'
ELSE
  ST_{MN} (t) = 'None'
END IF
JUMP : X_{MN} (t+1), Y_{MN} (t+1) = { X_{MN} (t) , Y_{MN} (t)}
  + $S_{MN} \angle$RAN(θ), (0$\leq \angle$RAN(θ)$\leq 2\pi$)
  IF r_{MN} (t+1) $> R_W$ **THEN**
    ST_{MN} (t+1)= 'None'
  END IF

Table 2. Threshold disconnection probability about to 3G and WiFi usage

3G area	R_W	S_{MN}
120 ·120 (m^2)	10(m) / 25unit	3(m)

P_{IN}=10% (fixed)	WiFi Utilization	Average number of Disconnection(1min)
P_{OUT} = 10%	61.9%	0.4
P_{OUT} = 15%	62.8%	1.6
P_{OUT} = 20%	64.2%	3.4
P_{OUT} = 25%	67.2%	6.6
P_{OUT} = 30%	70.7%	12.7
P_{OUT} = 35%	73.5%	19.9
P_{OUT} = 40%	76.6%	28.45

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