Modelling analysis of service quality improvement in mobile communications based on hard handover

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Abstract. Mobile communication systems make it easy for users to be able to do the communication process even in a mobile condition, one of which allows users to move from a cell area coverage to another cell area coverage, this movement phenomenon is called a handoff. Handoff is the process of diverting traffic channels automatically on a mobile station (MS) that is being used to communicate without termination. This paper analyzes the service quality improvement of the hard handover mobile communication network model from two to three base stations (BS) on the path loss parameter. Service quality parameters to be considered are the improvement of signal degradation and delay handover from two BS to three BS against the fixed and adaptive hysteresis methods.

1. Introduction
The development of traffic in cellular communication systems is increasing rapidly, while the available frequency spectrum is limited. To deal with these problems, an increase in channel capacity is carried out by cell splitting and frequency reuse [1]. In the cell division process, a handoff process is needed, where handoff is a process of automatically transferring traffic channels on a Mobile Station (MS) that is being used to communicate without termination [2]. Some criteria for finding a more optimal handoff algorithm used are the large number of expected handoffs, the least amount of unnecessary delay (optimizing the number of handoffs) because there is still a strong signal received by the user, the least signal degradation. Signal degradation occurs when the signal level is below the minimum signal degradation level by assuming that the signal strength of the transmitter is limited, the signal can be seen based on the same shape of the trajectory and traffic channel [3].

This paper analyzes the service quality improvement of the hard handover mobile communication network model as a function of the radio propagation loss parameters. Service quality parameters to consider are the improvement of delay handover from two BS to three BS for both fixed and adaptive hysteresis methods.

2. System model design
The mobile communication network that is designed is homogeneous, each consisting of 2 and 3 BS, namely: BS1 and BS2 and BS2, BS3 and BS3. To facilitate system modeling, each BS is placed on a cartesian system with coordinates BSi(xBSi, yBSi). Assuming each BS has equivalent cell coverage, with the hexagonal shaped cell model covered by the type of omnidirectional antenna. The distance d_{ik} is the distance MS to each to-k sample from BSi, Equation (1).
\[ d_{i,k} = \sqrt{(x_k - x_{BS_i})^2 + (y_k - y_{BS_i})^2} \quad (1) \]

Assuming the movement of MS in cellular system coverage is constant and has a straight direction with an angle of \( \theta \) \((0.2\pi)\), each sample time. Then, the coordinates of MS, namely; \((x_k, y_k)\) also changes with each sample time, Equation (1) dan (2) [3].

\[
x_k = r \cos \theta_{k-1} + x_{k-1} \quad (2)
\]
\[
y_k = r \sin \theta_{k-1} + y_{k-1} \quad (3)
\]

Where, \( r = d_s \) (the interval between samples), \( k \geq 2 \) (expresses sample to-k).

Each of the 2 BS and 3 BS network design models is shown in Figures 1 and 2.
The signal level received by MS from BTS_i along the d_{i,k} path.

\[ S_{i,k}(d_{i,k}) = K_1 - K_2 \log(d_{i,k}) + W_{i,k} \]  

(4)

Where, \( i = 1,2,3 \). \( S_{i,k} \): signal strength received from BTS_i into to-k sample, \( d_{i,k} \): distance of MS to BTS_i in the to-k sample, \( K_1 \): constant pathloss, \( K_2 \): path loss parameter, \( W_{i,k} \): Gaussian distribution \( N(0, \sigma_i^2) \), which represents the shadowing effect.

The \( W_{i,k} \) which is represented by the zero-mean AR-1 stationary Gaussian process that is characterized as an auto correlation function [4].

\[ E[W_{i,k}W_{i,k+m}] = \sigma_i^2 a_i^{|m|} \]  

(5)

\( W_{i,k} \) recursively written as follows:

\[ W_{i,0} = \sigma_i^2 N_{i,0} \]  

(6)

\[ W_{i,k+1} = a_i W_{i,k} + \sigma_i \sqrt{1 - a_i^2} N_{i,k} \]  

(7)

Where, \( N_{i,k}(0,1) \): random variable, \( d_i \): distance correlation, \( \sigma_i^2 \): shadow fading variance, \( a_i \): correlation coefficient of \( N_{i,k}, a_i = \exp(-v t_s/d_i) \).

3. Simulation method

Measurement of signal strength is done by taking each sample unit of signal strength from the BTS discrete every time \( t_k = k t_s \), where \( t_s \) is the sampling time period. The distance between each sample point \( s d_s = v t_s \). Signal strength measured by discrete \( S_{i,k} \), from BS_1 every time to \(-k\) in dB, is modeled by Equation (7).

\[ S_{i,k} = P_{k,i} + W_{k,i} + Z_{k,i} \]  

(8)

Where \( P_{k,i}, W_{k,i} \) and \( Z_{k,i} \) each representing a pathloss component, shadow fading effect, and fast fading.

\[ P_{k,i} = S_{tr,i} - 10 \eta \log d_{i,k} \]  

(9)

Where:

\( S_{tr,i} \): strong signal sent by BS_1 in dB units.
\( \eta \): factors for path loss depends on the environmental system propagation.
\( d_{i,k} \): The MS distance form BS_1 in the to-k sample.

In Table 1 is a grouping of path losses \( \eta \) grouping based on the type of propagation system environment.
Table 1. Path loss factor values.

| Environmental Type                  | Exponential Path loss parameters |
|-------------------------------------|----------------------------------|
| Free Space                          | 2.0                              |
| Radio Cellular Urban Area           | 2.7 - 3.5                        |
| Radio Cellular SubUrban Area        | 3.0 – 5.0                        |
| Barrier Free Buildings              | 1.6 – 1.8                        |
| Barrier Buildings                   | 4.0 – 6.0                        |
| Factory Area                        | 2.0 – 3.0                        |

The signal strength level received by the MS is sampled discrete every \( t_k = k t_s \), where \( t_s \) is the sampling time period. The distance of each sample point is \( d_s = v \cdot t_s \), assuming the speed of MS \( v \) (meters/second) is constant. To refine or minimize the influence of a fluctuating signal, the signal level received by MS is processed by an exponential average process so that the signal level equation after averaging can be written in Equation (10) [4].

\[
\bar{S}_{i,k}(d_{i,k}) = e^{-\frac{d_s}{d_{\text{rata-rata}}}}\bar{S}_{i,k}(d_{i,k-1}) + \left(1 - e^{-\frac{d_s}{d_{\text{rata-rata}}}}\right)\bar{S}_{i,k}(d_{i,k})
\] (10)

Where:
- \( d_{\text{average}} \): Average length of window
- \( \bar{S}_{i,k}(d_{i,k}) \): the average signal received by MS from BSi as a function of distance \( d \), at to-k signal sample.
- \( \bar{S}_{i,k}(d_{i,k-1}) \): the average signal received by MS from BSi as a function of distance \( d \), at the sample is to-k-1.

3.1 Fixed hysteresis method

In the Hysteresis method, handoff initiation will occur when the signal strength of the active BS is higher than the candidate BS signal strength of the hysteresis \( H \) value, notated in Equation (11).

\[
(\bar{S}_{k\text{andidat}} > \bar{S}_{\text{aktif}} + H)
\] (11)

Where \( H \) is the value of the hysteresis specified. This strategy can prevent the ping-pong effect, reducing the number of handoffs and increasing the delay.

3.2 Adaptive hysteresis method

At the threshold with adaptive hysteresis, the handoff event starts when the signal strength of the active BS that is serving MS is under a certain threshold value [5]. While the candidate BS signal is higher than the signal can be written Equation (12)

\[
(\bar{S}_{\text{aktif}} < \Theta_0) \cap (\bar{S}_{k\text{andidat}} > \bar{S}_{\text{aktif}} + H_{\text{adaptif}})
\] (12)

The adaptive hysteresis varies based on distance function. Equations for adaptation are written in Equation (13).
\[ H_{\text{adaptif}} = \max \left\{ 20 \left( 1 - \frac{d^4}{R^4} \right), 0 \right\} \]  

Where, \( H_{\text{adaptif}} \): Adaptive Hysteresis, \( d \): Distance and \( R \): Cell radius

### 3.3 Delay handoff

Delay is a delay that MS is not served by the BTS closest to MS. The MS position passes through the midpoint of the cell in an identical BTS area. The midpoint indicates that the signal level of the BTS is the same, assuming there is no noise in the cellular environment.

Delay handoff (Delay(\( l \))) is the length of MS not served by the nearest BTS along the path \( l \) that consists of the \( N \) signal sample points, which are expressed in Equation (14).

\[ \text{Delay}(l) = \sum_{k=1}^{N} \Delta_k \]  

Where, \( \Delta_k = \begin{cases} t_s & \text{if a delay occurs} \\ 0 & \text{otherwise} \end{cases} \)

So, the average delay (\( \overline{\text{Delay}} \)) of a number \( s \) of trajectories \( l \) is formulated by Equation (15).

\[ \overline{\text{Delay}} = \frac{1}{s} \sum_{l=1}^{s} \text{Delay}(l) \]  

### 4. Result and discussion

For the fixed hysteresis method, the hysteresis value was determined to be 4 dB [6], while the adaptive hysteresis method was varied from 0 to 20 dB which changed based on the MS distance to BS function. Data output simulates the influence of parameters the path loss to signal degradation is shown in Table 2.

**Table 2.** Variation of path loss parameters on signal degradation.

| Exponential parameter of path-loss (unit) | Signal Degradation (prob) | Hysteresis 4 dB | Adaptive |
|------------------------------------------|---------------------------|-----------------|----------|
|                                          | 2 BS  | 3 BS | Improve ment (%) | 2 BS  | 3 BS | Improve ment (%) |
| 2.0                                      | 0.0003 | 0.0003 | 0.0000 | 0.0003 | 0.0003 | 0.0000 |
| 2.5                                      | 0.0003 | 0.0003 | 0.0000 | 0.0003 | 0.0003 | 0.0000 |
| 3.0                                      | 0.0003 | 0.0003 | 0.0000 | 0.0003 | 0.0003 | 0.0000 |
| 3.5                                      | 0.0003 | 0.0003 | 0.0000 | 0.0003 | 0.0003 | 0.0000 |
| 4.0                                      | 0.0003 | 0.0003 | 0.0000 | 0.0003 | 0.0003 | 0.0000 |
| 4.5                                      | 0.1436 | 0.0019 | 98.6769 | 0.1471 | 0.0030 | 6 |
| 5.0                                      | 0.2818 | 0.2732 | 3.0518 | 0.3719 | 0.3697 | 0.5916 |
| 5.5                                      | 0.4302 | 0.4189 | 2.6267 | 0.4998 | 0.4995 | 0.0600 |
| 6.0                                      | 0.5779 | 0.5841 | 1.0728 | 0.4999 | 0.4997 | 0.0400 |

Signal degradation increases with increasing path loss parameter values. Signal degradation for 3 BS is generally smaller compared to 2 BS. The highest percentage of signal improvement was
98.6769 percent when the path loss parameter was 4.5. The comparison graph of signal degradation to the parameter path loss between 2 BS and 3 BS for 4 dB Hysteresis is shown in Figure 3.

![Figure 3](image)

**Figure 3.** Comparative graph of signal degradation to the parameter part loss between 2 BS and 3 BS for 4 dB hysteresis.

While, the graph of signal improvement for adaptive hysteresis from 2 BS to 3 BS is shown in Figure 4. The biggest percentage of signal improvement is 97.9606 percent when the path loss parameter is 4.5.

![Figure 4](image)

**Figure 4.** Comparison of signal degradation graphs with the parameter part loss between 2 BS and 3 BS for 4 dB hysteresis.

In Table 2 data show that signal degradation for the adaptive hysteresis method is generally greater than for fixed hysteresis, both for 2 BS and for 3 BS. The comparison graph of signal degradation to the path loss parameter 3 BS for the fixed Hysteresis method with the Adaptive Hysteresis method is shown in Figure 5.
Figure 5. Comparison of signal degradation graphs with 3 BS path loss parameters between the fixed Hysteresis method and the adaptive hysteresis method.

Simulation output data from the effect of the path loss parameter on the Handoff average delay is shown in Table 3.

| Parameter of path-loss (unit) | Average delay time (m/s) | Improvement (%) |
|-----------------------------|--------------------------|-----------------|
|                            | Hysteresis 4 dB          | Adaptive        |
|                            | 2 BS 3 BS                |                 |
| 2.0                        | 116.8 109.8              | 6.0 0.0         | -               |
| 2.5                        | 116.7 109.0              | 6.6 0.0         | -               |
| 3.0                        | 116.1 106.9              | 7.9 0.0         | -               |
|                            | 479 324                  | 4 3            | 32.4            |
| 3.5                        | 491.5 336.0              | 31.6           |                 |
|                            | 1080 335                 | 1080 335       |                 |
| 4.0                        | 1080.0 344.8             | 68.1            | 0.0 0.0         | 69.0            |
|                            | 1080 335                 | 1080 335       |                 |
| 4.5                        | 1080.0 355.1             | 67.1            | 0.0 0.0         | 69.0            |
|                            | 1080 335                 | 1080 335       |                 |
| 5.0                        | 1080.0 364.7             | 66.2            | 0.0 0.1         | 0.0             |
|                            | 1080 335                 | 1080 335       |                 |
| 5.5                        | 1080.0 403.2             | 62.7            | 0.0 0.3         | 0.0             |
|                            | 1080 335                 | 1080 335       |                 |
| 6.0                        | 1080.0 401.1             | 62.9            | 0.0 0.4         | 0.0             |

From Table 3 it is shown that the average number of delay handoffs increases as the value of the path loss parameter increases. This is because, by increasing the path-loss parameter the signal strength will decrease due to high attenuation. So the system will wait a longer time to get a better signal. The average delay of the fixed hysteresis method handoff for 2 BS is higher than that of 3 BS, as shown in Figure 6.
Likewise, the average delay of the Hysteresis Adaptive Handoff method for 2 BS is higher than that of 3 BS, as shown in Figure 7.

At Table 3 it is also shown that the average delay of the adaptive Handoff method is smaller than the fixed Hysteresis method at 2 BS and 3 BS. A comparison chart of the two methods for 3 BS is shown in Figure 8.
5. Conclusion

It has been successfully modeled to improve the quality of service from the hard handover mobile communication network model from two to three base stations (BS) on the path loss parameter. From the results of the comparison of the two methods between the adaptive hysteresis method and the permanent hysteresis method, the best method to use is the adaptive hysteresis method because the amount of delay is small and the signal below the minimum level is less than the fixed hysteresis method.

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