# Educational Emulation of a Soft Handoff Teaching Model (EESH-TM): Envisioning the Gradual Signal Decrease-Increase Mechanism Between Base Stations in Cells

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**Abstract**

The use of fixed Base and Mobile Stations offer a set of challenges dealing with the movement of a Mobile Station away from one Base Station toward a second Base Station. In this situation, the signal strength decreases as the distance of the mobile position increases (following an inverse-square law) from the first station; while an increase in signal strength is experienced as the distance decreases from the second one. Gradually the signal from the former is lost. This is a difficult problem in wireless technology, not only to picture but also to solve. This problem which is prominent in mobile and wireless applications is called "Soft Handoff", the solution of which applies the concept of *"make-before-break"*, which postulates the smooth and gradual transition of signals from the previous Base Station to the next one without causing a sharp break or interruption of the signal. Such a hypothetically smooth and soft hand over signal mechanism is very difficult for students to understand especially those who have had little or no experience with telecommunication equipment, with the analysis of wireless circuits or with hands-on experience with the technology. This became evident when the topic was initially covered in a Telecommunications course at University of Namibia. It was within this context that the Educational Emulation of Soft Handoff Teaching Model (EESH-TM) was designed and developed to model the mechanism of Soft Handoff. The EESH-TM is comprised of: two Base Stations, two Cells, a Mobile Station, and two interacting signals. This teaching model clearly demonstrated, step-by-step, various scenarios with a mobile unit moving between two Base Stations clearly illustrating how Soft Handoff works. Hence, the utilization of this teaching tool presented inexperienced students with an opportunity to observe and understand how signal hand off works in a wireless network. The success of the model was demonstrated by higher examination scores and greater student interest in the topic.

**Keywords**: EESH-TM, Base Station, Cell, Mobile Station, envision, signal strength, signal decrease, signal increase and emulate.

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# 1 Introduction

Educational Emulation of Soft Handoff Teaching Model (EESH-TM) was conceived as a class room tool, especially for poorly funded institutions such as those in sub-Saharan region to demonstrate step-by-step the mechanism of Soft Handoff. The concept of Soft Handoff is a complicated telecommunication task that may be difficult for some students to visualize and master. Wong (1997) defined the Soft Handoff as a conditional decision made on when to hand off and depends on changes in pilot signal strength from the two or more Base Stations. This decision is normally made after it was clear that the signal from one Base Station was considerably stronger and dominated those from the others. He further presented a Soft Handoff as an athletic metaphor, i.e., "a track and field relay race, where a baton is passed from one runner to the next after the second runner starts running, and so for a short time they were both running together, hence a Soft Handoff". Also, Shue et al. (2007) emphasized that Soft Handoff was a widely known decisive feature in a CDMA-based cellular network which was processed by a *"make-before-break"* method where a network is configured that to break (open) the first set of contacts before engaging (closing) the new contacts. This prevents the momentary connection of the old and new signal paths. In other words, it shuts down the signal from one Base Station before it is handed off to the other. Others, like Rodionov et al. (2002) stressed that the same frequency band could be used simultaneously over neighboring Cells in CDMA cellular systems thus allowing a smooth transition as the Mobile Station moved. This enabled Soft Handoff to occur when a new Base Station (BS) was assigned to a mobile unit still served by the old one and would be serviced by it until reaching some outer handoff border where another Base Station would take over. Khumsi et al. (2005) simply defined handoff as a process that allowed a Mobile Station in movement to continue without signal interruption when it moves from one Cell to another.

The EESH-TM composition was demonstrated in Figure 1, showing the major components used in the mechanism involved and these are: Cell A, Cell B, Base Station A (its coverage area), Base Station B (its coverage area) and Mobile Station (MS).

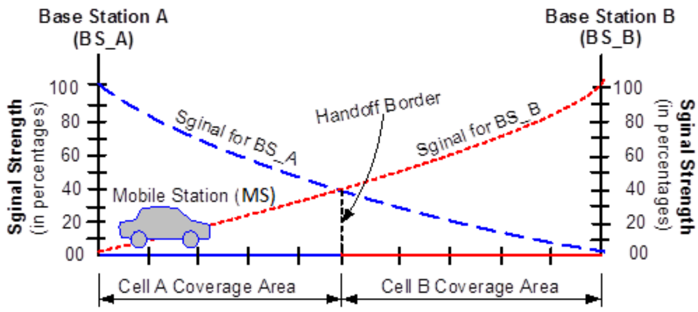


Figure 1: Soft Handoff Mechanism in Cells Coverage areas

From Figure 1, for easier identification and interpretation of the EESH-TM mechanism, the Cell A coverage area and signal for BS_A are colored blue, whereas, for Cell B and signal BS_B are indicated in red. The diagram shows several important features of the model. It illustrates the physics of the signal as following an inverse squared law. It also shows that when the signal strength from the first Base Station falls to a certain level (50% in this example) and a signal from the second tower is detected at or about the same signal strength this forms the outer boundaries of the Cell coverage area and hand off occurs. Nevertheless, the diagram does not indicate whether there is any change or shift in frequency. However, the mechanism of the EESH-TM will be discussed and illustrated in detail in later Sections.

### 1.1 Problem Statement

Students from rural schools in the sub-Saharan region often face serious problems when it comes to practical lessons involving most ICT courses. Usually there is a dearth of hardware with which to practice. This problem is especially acute for those students taking courses involving telecommunications, computer networks, etc., where equipment such as Base Stations, antennas, access points, satellites but to mention a few may not even be available at their countries' national level, let alone be on hand at the local level for educational purposes. Even at well-funded institutions it is difficult to bring telecommunications equipment into classroom as they often involve large capital expenditures and may be installed in static configurations in distant locations. In fact, while wealthy institutions in urban areas may face the same problem, they may have an advantage of proximity not only to technical installations but to ICT providers and technologists, and may have access to these locations and experts. But for institutions located in remote areas, their students may have to surmount larger barriers to learning. Consider the problem of teaching students the concepts of such equipment when they may have never had any first-hand experience of even using ICT technology, let alone understanding how it works. Under these circumstances, an unsophisticated student may find difficult to grasp the operations of such technology. In the particular case of Soft Handoff which was described above, the situation can be aggravated by the fact that many students from remote areas may never have been exposed to either cellular or wireless technology, making the concept even more difficult to understand.

To overcome this problem, the EESH-TM system was created to simulate the mechanism of Soft Handoff of signals as the mobile moves away from its old Base Station and gaining signals as it moves towards the new Base Station. In that way, the learners are able to ”virtually” observe the gradual decreasing of signals from the former Base Station at the same time to actually visualize a smooth increase of signals strength as it heads toward the new Base Station. As the saying goes, ”it is easier to remember what you saw…” Therefore, this model emphasizes the key concepts of Soft Handoff and compels learners to remember that signal strength decreases as the Mobile Station moves from the old Base Station and increases as the it moves towards the new base Station.

## 2 Literature Review

The mechanism of Soft Handoff in the mobile communication was discussed by many vendors and while the key concepts were briefly presented in the introduction, for engineers and technologists the concepts demand a deeper examination. Wong (1997) related the Soft Handoff mechanism as analogous to a track-and-field relay race, where the baton is passed from one runner to the next after the second runner starts running, and so for a short time they are both running together, analogous to a Soft Handoff. He also gave a technical illustration by emphasizing that depending on the changes in pilot signal strength from the two or more Base Stations involved, a hard decision will eventually be made to communicate with only one and this normally happens after it is clear that the signal from one Base Station is considerably stronger than those from the others. He went on to give an explanation that in Soft Handoff there was no hysteresis margin, thus, unnecessary handovers were reduced and delay time was minimized, resulting in less delay and equivalent to ”instantaneous” macroscopic selection diversity (an improvement in the effectiveness of a signal channel) and clarified this as accomplished by "instantaneous" switching to the best Base Station signal during a Soft Handoff (uplink) and avoided the additional interference associated with handoffs with hysteresis.

Kim et al. (1999) pointed out that CDMA systems supported Soft Handoff, which was a make-before-break method. They stressed that when the pilot signal from a new Base Station (BS) was stronger than the threshold value "T_ADD", a new link to the BS was established while maintaining the existing link. They assumed that a Mobile Station could be in Soft Handoff with two strong BS's. They also emphasized that when the pilot signal from either the old BS or the new BS weakens to below "T_DROP", the bad connection was released and only a single good connection was maintained after that time. This was supported by CDMA Handbook (1999), Gilhousen et al. (1992) and Viterbi et al. (1994) Soft Handoff increases handoff traffic by using multiple channels and also increases signaling traffic, network processing, and the amount of radio equipment required at the BS's. They explained that Soft Handoff was a technique whereby mobile units in transition between one Cell and its neighbor transmit to and receive the same signal from both BSs simultaneously. They also emphasized that the decision to enter Soft Handoff and when to release the weaker (older) Base Station generally depended on the relative signal strengths. Others like Lee et al. (1998), Lee (1991) and Kwabi (1992) defined Soft Handoff in cellular code-division multiple-access (CDMA) systems as a technique whereby mobiles near Cells boundaries communicate the same transmitted signals to more than one Base Station within their vicinity.

Under the Soft Handoff mechanism, Sheu et al. (2005) illustrated the pilot signal strength of a Base Station that a Mobile Station (MS) could detect as an inversely proportional to the distance between MS and Base Station. They further stated that when the pilot signal from a new Base Station was stronger than a threshold value "T_ADD", a new link to the new Base Station was established while the old link to the old Base Station was still maintained. They cited a scenario that in a normal operation, if a pilot signal from the third Base Station becomes stronger than either of the two existing pilot signals, a handoff may occur and the call would drop the weakest link so that only two links were available in any given time interval.

Rao et al. (2010) first described handoff as when a call had to be handed off from one Cell to another as the user moved between Cells. They stated that a full idea of a Soft Handoff scheme was to ensure that there was connectivity with the old Base Station while the new one had been assigned to take control over the communication link. In that they assured, at a given instant of time, the mobile maintaining a constant communication link with at least one Base Station simultaneously ensuring a non disrupted call activity. They emphasized that such an algorithm may be designed in such a way as to ensure that as soon as the mobile was within the range of the new Cell, the old Base Station released the connection of the call. They finally analyzed that Soft Handoff ensured a continuous link to the Base Station from which the strongest signal was issued.

# 3 The EESH-TM Mechanism

Figure 2 shows the main interface of the EESH-TM model. It shows the two Base Stations on opposite sides of the display. Cell A, with a Base Station A (BS_A) and Cell B also with a Base Station B (BS_B); a small icon of an automobile represents the Mobile Station which moves along a straight line connecting the two BSs. In between these two BSs at the center of the line, vertical line is placed which establishes the Cell boundaries or borders. Above the line linking these two Cells, there is a rectangular Cell Dialog Box (CDB) which indicates the process being carried out at each stage. Above the rectangular CDB is a Twine Window (TW) subdivided into two parts by another horizontal line. In this TW the upper one represents the BS_A in the first Cell, Cell A. The initial state of the simulation requires the MS to be positioned at the left such that it acquires the full signal strength generated from BS_A. In this work the signals from BS_A and associated with Cell A are colored green for identification. In the same TW, the lower window illustrates the BS_B which is in the next Cell B away from the MS and which in its initial state will be empty since the MS has not yet begun its journey toward the BS_B. Nevertheless, as the simulation proceeds and its signal strength appears in the lower frame of the TW and its strength will be colored red. There are also buttons to interactively START the simulation; to CONTINUE the simulation; and to EXIT to terminate the simulation.

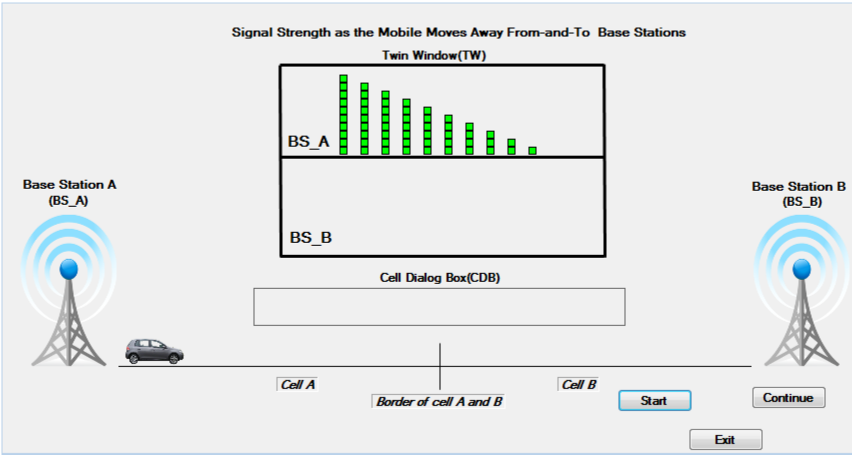


Figure 2: Mobile Station in Cell A at BS_A

For easier understanding the mechanism of this Soft Handoff of signals as the MS moves from one Cell to another, a bar graph of signal strength is provided. Each bar is further subdivided into or comprised of smaller squares. Each square represented in each bar depicted in Figure 2 represents a ten percent (10%) signal strength. From the figure, the highest signal close to the BS_A, in Cell A has ten (10) squares which would amount to hundred percent (100%) acquisition of signal strength. Therefore, the MS at BS_A obtains a full acquisition of signal strength which amounts to hundred percent (100%), whilst in the next Cell, Cell B, there is zero percent (0%) acquisition of the signal as the mobile is not yet within the range of this Cell.

To maintain consistency with previous discussions of the Cells, and Base Stations, let the ones where the MS started from in this case Cell A and BS_A be named "old Cell" and "old BS", respectively. Then the next Cell, Cell B and BS, BS_B be referred to "new Cell" and "new BS" respectively. As the MS starts moving away from the BS_A, it gradually started losing some signal strength as demonstrated in Figure 3.

As the MS moves away from the BS_A, Figure 3 illustrates how it had lost two squares that translate into twenty percent (20%) loss of signal strength and it retained eight (8) squares that reflect eighty percent (80%) of the total signal strength. At that stage, the same MS started gradually acquiring some signal strength from the next Base Station, BS_B. In this case MS has acquired some two squares that computed to twenty percent (20%) signal strength. Such a process of losing and gaining signal strength as the MS moves away from the old BS towards the new one marks the beginning and establishment of the Soft Handoff mechanism. As the MS continued to move, the

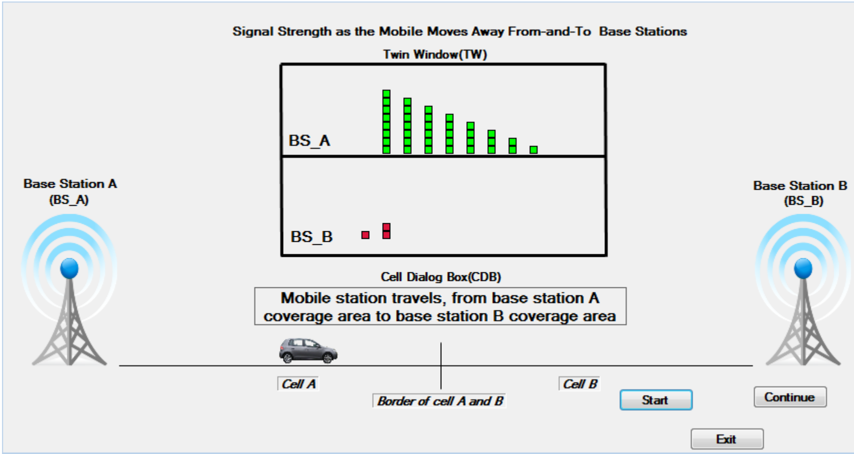


Figure 3: MS Start Moving Away From BS_A

CDP continued to give the status of the process going on at every stage. At this stage from the figure it was indicating that ”Mobile Station travels, from Base Station A coverage area to Base Station B coverage area”.

The MS continued moving away from the old BS until it reached the border of Cell A and Cell B, which was half the distance between the two Base Stations, BS_A and BS_B as demonstrated in Figure 4.

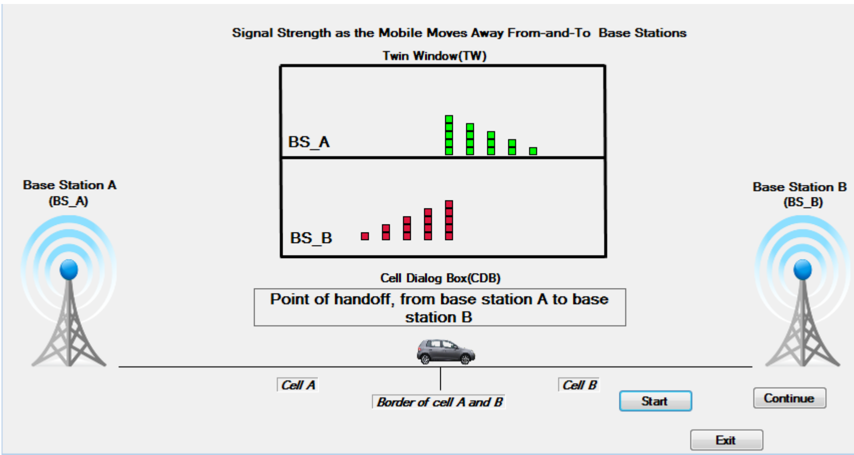


Figure 4: MS at the Border of Cells

As the MS reached the border of Cells, it (MS) had lost five (5) squares that were fifty percent (50%) loss of signal strength from the old Cell and BS. At the same time, the MS gained five (5) squares translating to fifty percent (50%) signal strength from the new Cell and BS. This was a critical point of Soft Handoff as the amount of signal strength loss from the old Cell and BS were equal to that gained ones from the new Cell and BS. The CDB continued to give the status of process going on by stating. ”Point of handover, from Base Station A to Base Station B.”

Now the MS continued travelling in the new Cell towards the new BS, BS_B, and at this stage the signals from the old Cell and BS were gradually diminishing as demonstrated in Figure 5.

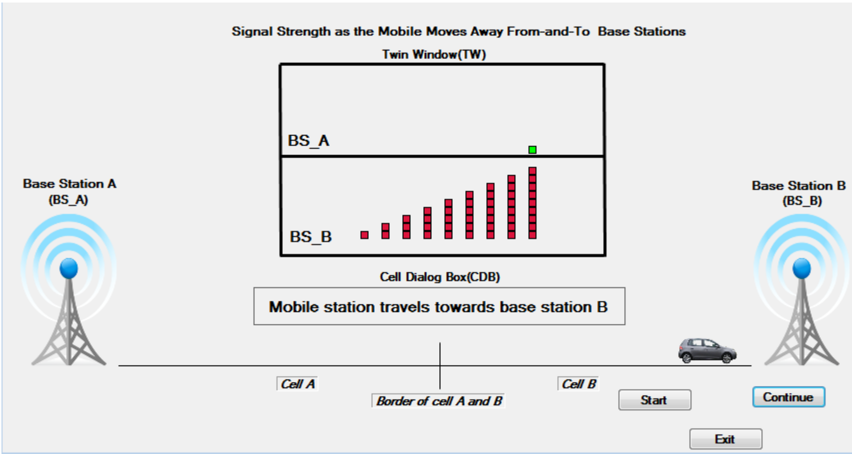


Figure 5: Mobile Station Nearing Base Station B

At this stage MS had lost nine (9) squares from the old Cell and BS which was translating to ninety (90%) diminishing of the signal strength and only ten percent (10%) remained. On the other hand the same MS had now gained the total of nine (9) squares that computed to ninety percent (90%) signal strength. The CDB continued to give the processing status, in this case as, "Mobile Station travels, from Base Station A coverage area to Base Station B coverage area."

As the MS moved towards the BS_A, there were no more squares from the old Cell and BS, which meant that the Soft Handoff was completed. At that stage the MS had acquired ten (10) squares that translated to hundred percent (100%) gaining of the signal strength as indicated in Figure 6.

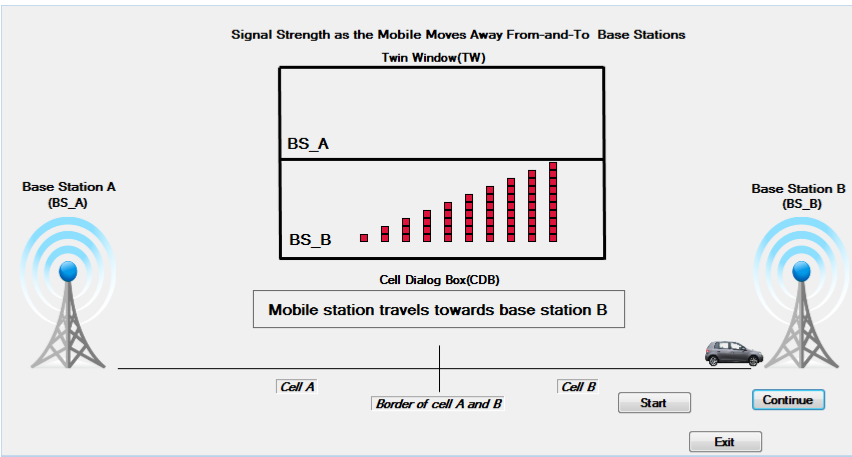


Figure 6: Mobile Station Arrived at Base Station B

As MS got stationed at the BS_B, it acquired the hundred percent of the signal strength as already discussed above. Whereas, at the old BS, it had completely no signal. From the above illustration, this marked the complete Soft Handoff.

# 4 Discussion

The mechanism of Soft Handoff, where the MS as it moved away from the old Cell and BS had the signal strength decreased, whereas, the MS approached the new Cell and BS, the signal strength increased was discussed above extensively. When the MS was at the old Cell and BS, it had hundred percent (100%) signal strength, but the new Cell and BS had zero percent (0%) of signal strength. However, as the MS was moving away from the old Cell and BS, the signal strength was gradually decreasing and inversely increasing for the new Cell and BS. From this demonstration and in this work, it was concluded that the signal strength of the MS in the old Cell and BS was inversely proportional to that of new Cell and BS as illustrated in Figure 7.

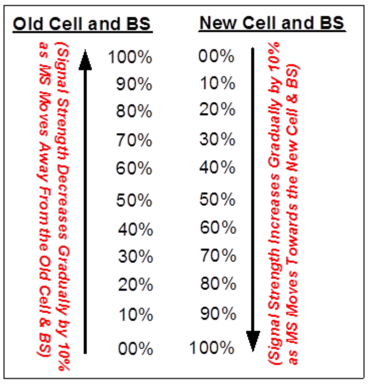


Figure 7: Inverse Proportional of Signal Strength of Old versus New Cells and BSs

From Figure 7, it was evident that at every 10% decrease of signal strength in the old Cell and BS, there was also 10% increase in the new Cell and BS. Such a proportional even gradual change facilitated the smooth handoff of signals from the old Cell to the new one. This is a direct result of the inverse squared law where signal strength can be described by the simple expression: Signal Intensity = Power/$R^2$ where $R$ = distance between a Base Station and a Mobile Station.

# 5 Conclusion

The Educational Emulation of Soft Handoff Teaching Model (EESH-TM) was conceived as a class room teaching aid to demonstrate step-by-step, the mechanism of Soft Handoff which is applied in mobile and wireless applications. The mechanism of transitional and gradual hand over of signals from one Base Station to the other is a difficult concept to grasp especially for inexperienced students who have not been widely exposed to ICT in general and wireless and mobile technology in particular. The EESH-TM in Figure 1, offers a simple but effective modeling of the Soft Handoff. As shown in Figures 2 through 6, as they demonstrate the Soft Handoff mechanism step-by-step illustrating the movement of the Mobile Station away from the old Base Station travelling towards the new BS. Figure 4 demonstrates the implementation of Soft Handoff mechanism. In this way, the students are accorded an opportunity to see this transitional handoff as if it were the actual and physical implementation and offered a way for students to obtain a concrete idea of a rather abstract concept. EESH-TM was not meant to a complete representation of physical reality, for example it only captures the simple signal interactions of two Cells and a single Mobile Station, a more comprehensive model would include multiple Base Stations and might also include hand offs that involve not only signal transitions from one Base Station to another but also hand offs accompanied by a shift in frequencies. But the basis of any effective model is to capture the key features of a physical phenomenon while minimizing complicated but less relevant factors. In this manner the model served its purpose. We have had success with our students as measured by improved examination scores, research assignments and class room discussions.

**Acknowlegements**

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