# A Dual-antenna Based Handover Scheme for GSM-R Network


**Pengyuan Du Lujin Luo Yongsen Ma Chengnian Long**

Department of Automation, Shanghai Jiao Tong University, China

# Outline

- Introduction
- Traditional Handover Scheme
- Dual-antenna Handover Scheme
- Simulation and Performance Analysis
- Conclusion

# Introduction

- Recently, the development of high-speed railway has caught the attention of countries all over the world. ***GSM-R*** (GSM for Railways) network is specialized in mobile communication and it has been adopted by many countries to serve for different railway systems.
- ***Handover*** is the key technology in the mobility management of GSM-R network and it keeps wireless communication between the Base Station (BS) and Mobile Station (MS) from dropping. The effectiveness of the handover process in GSM-R network is crucial for improving the overall system

# Outline

- Introduction
- Traditional Handover Scheme
  - Handover scheme
  - Latency analysis
  - Motivation of our work
- Dual-antenna Handover Scheme
- Simulation and Performance Analysis
- Conclusion

# Handover scheme



- The conventional handover scheme in GSM-R network is basically the same as that in GSM network.
  - ✓ Measurement procedure
  - ✓ Handover procedure
  - ✓ Execution procedure
- Different handover methods could be adopted in the handover procedure, and we introduce three kinds of handover method [1].
  - ✓ The *Threshold* method
  - ✓ The *Hysteresis* method
  - ✓ The *Threshold with Hysteresis* method

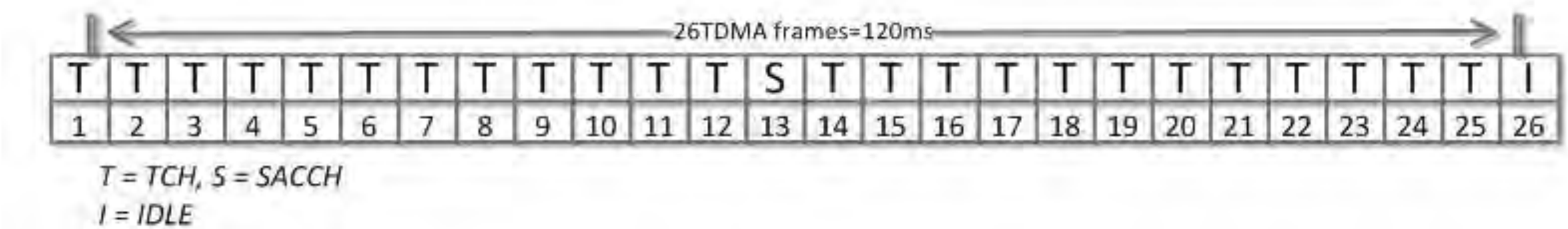
[1] M. Ergen, S. Coleri, B. Dundar, A. Puri, J. Walrand, and P. Varaiya, "Position leverage smooth handover algolithm for mobile IP," in Proc. of IEEE ICN, August 2002.

# Latency analysis

- In the conventional handover scheme, latency incurred in the measurement procedure is given by:

$$T_m = \tau_m \times Hrequave$$

where $\tau_m$ is 0.48s, according to the frame structure of TCH, $Hrequave$ is usually 4. Therefore $T_m$ is about 2s.




Frame structure of TCH.

# Latency analysis

- Latency incurred in the execution procedure $T_e$ is
- 0.2s for handover between Base Transceiver Station (BTS);
- 0.532s for handover between Base Station Controller (BSC);
- 1.358s for handover between Mobile Switching Center (MSC).

- Therefore the overall latency incurred in the single-antenna based handover process is given by:

$$T_h = T_m + T_e$$

# Motivation

- When train speed goes beyond 300km/h, signal strength decreases so fast that the intrinsic handover latency becomes unacceptable.
- As a consequence the conventional handover scheme cannot satisfy the demands of wireless communication in high-speed scenario.

How could we overcome the problem of handover latency in high-speed scenario?

# Outline

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

- Introduction
- Traditional Handover Scheme
- **Dual-antenna Handover Scheme**
  - Dual-antenna system
  - Dual-antenna handover scheme
  - Insight analysis
- Simulation and Performance Analysis
- Conclusion

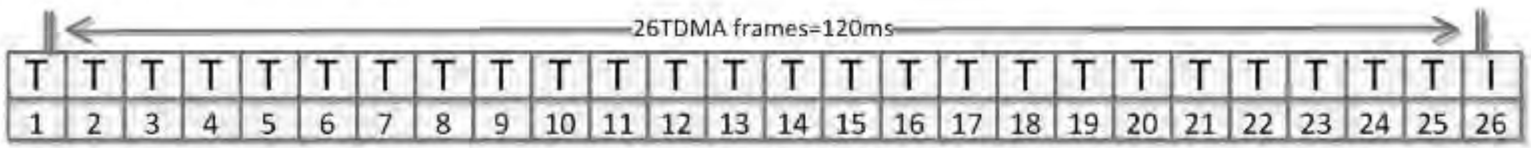
# Dual-antenna system

- The conventional handover scheme is based on single antenna, and it should transmit both of the measurement report and encoded speech or. We believe that this is the key reason of the latency incurred in the measurement procedure and cause the disconnection during the handover process.
- We use dual-antenna system to solve the problem.
  - ✓ We adapt the frame structure of TCH to distinguish the transmission of measurement report and encoded speech or data.
  - ✓ We allocate these two transmissions to the two antennas so that technically the two antennas perform different functions.
  - ✓ The two functional antennas could complete seamless handover process collaborately.

# Dual-antenna system

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

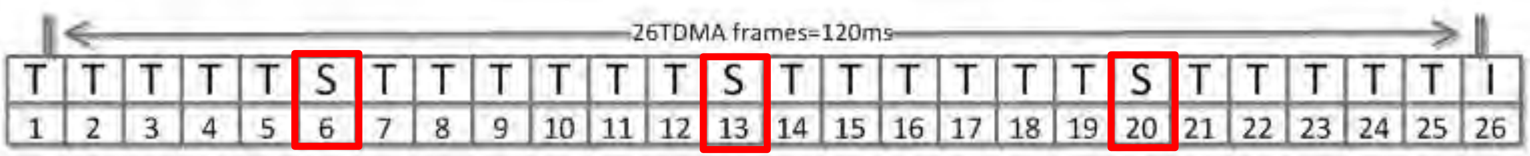
- To fully take the advantage of dual-antenna system, we modulate the frame structure of the original TCH and get two kinds of functional TCH.
  - ✓ ***Full TCH*** is only in charge of the transmission of encoded speech or data.




*T = TCH, I = IDLE*

Frame structure of Full TCH

  - ✓ ***Hybrid TCH*** performs almost the same as the original TCH except that the number of SACCH in it is increased and therefore the measurement report is sent more quickly.

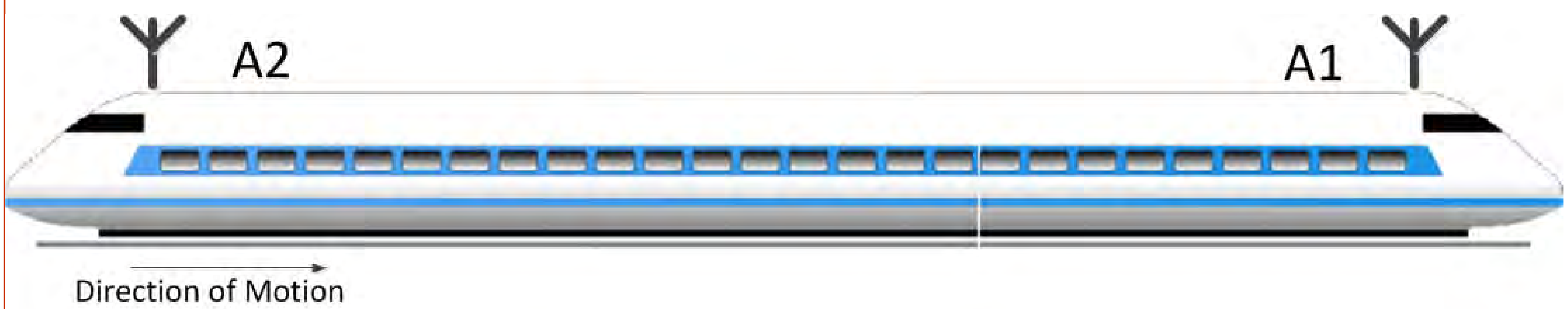



*T = TCH, S = SACCH*
*I = IDLE*

Frame structure of Hybrid TCH

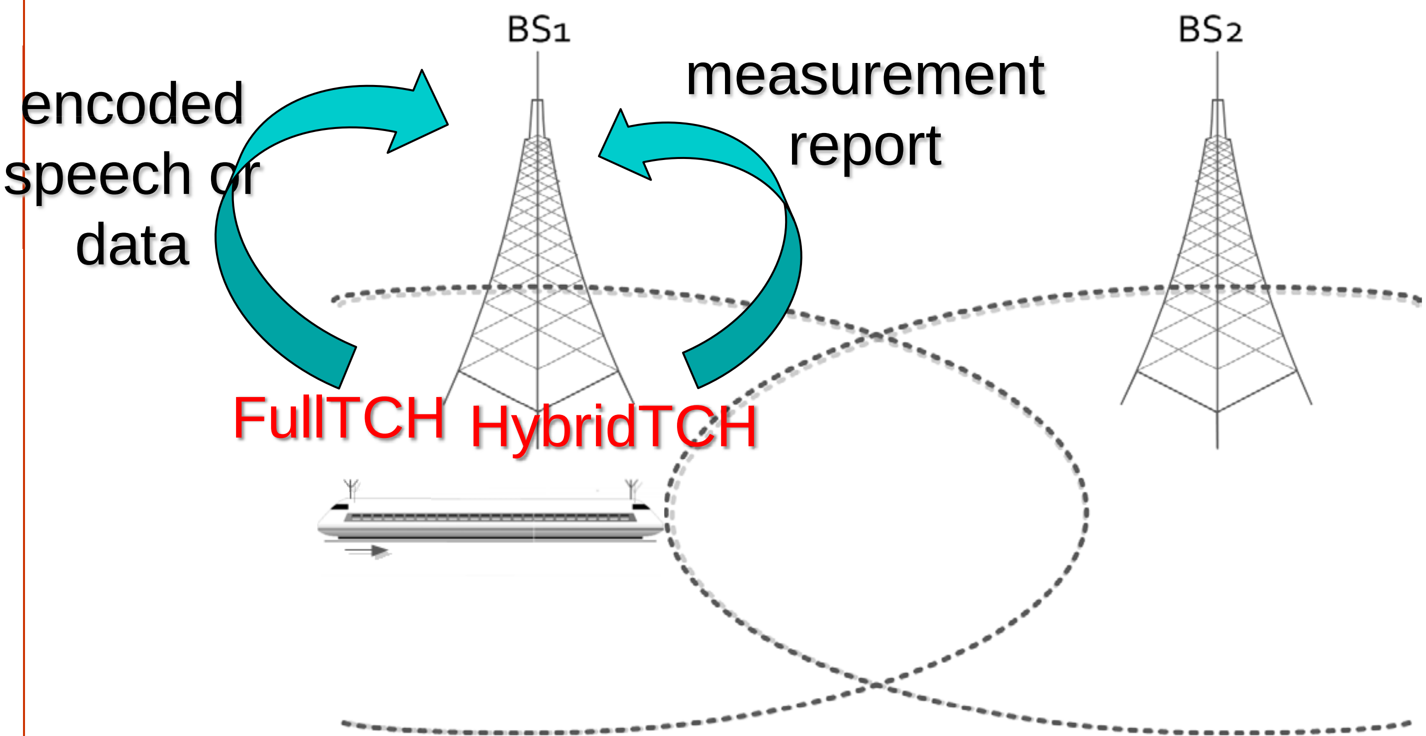
# Dual-antenna based scheme

- **Basic assumption**
  - ✓ In our handover scheme the International Mobile Subscriber Identification Number (IMSI) of the front antenna and the rear antenna should be related. After they have access to GSM-R network, Visitor Location Register (VLR) could identify the two antennas and guarantee that the dual-antenna system collaborate with BS and complete the whole handover process.



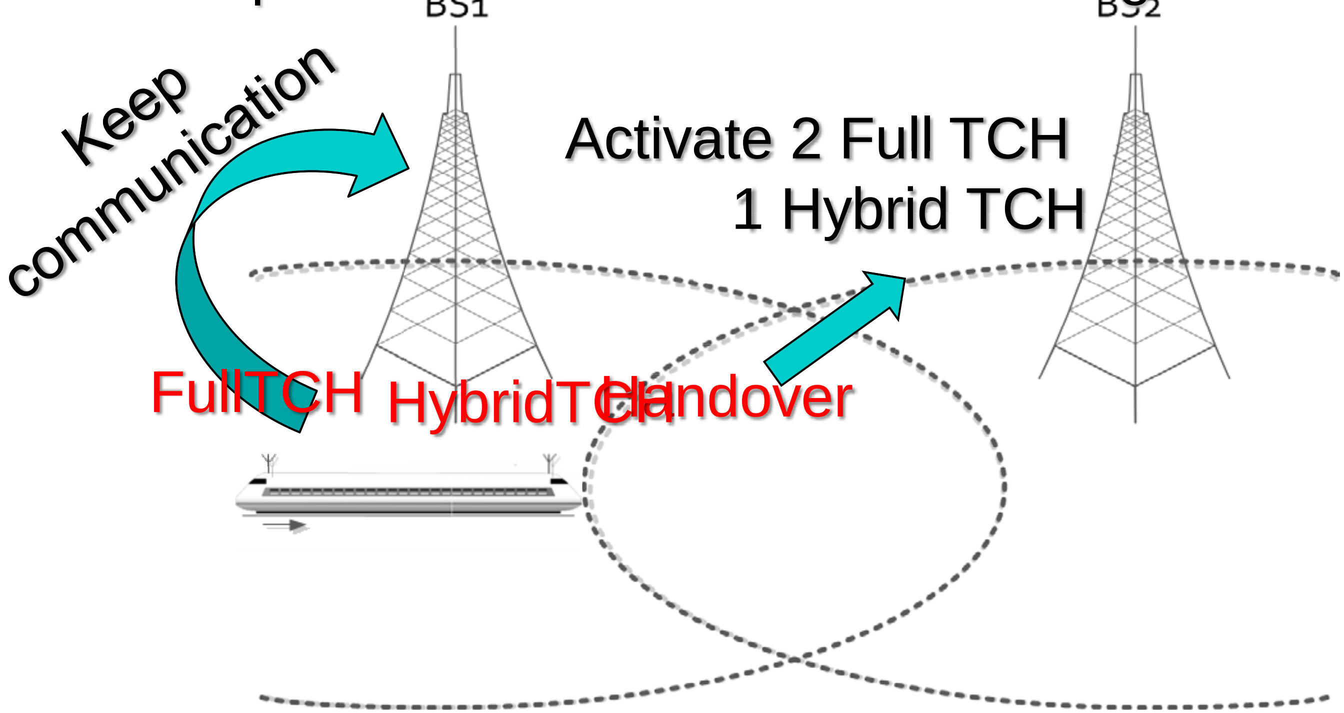
# Handover process 1

- At first, the train is within the coverage area of BS1.
- A1 connects to Hybrid TCH for transmitting measurement report
- A2 connects to Full TCH for transmitting encoded speech or data.



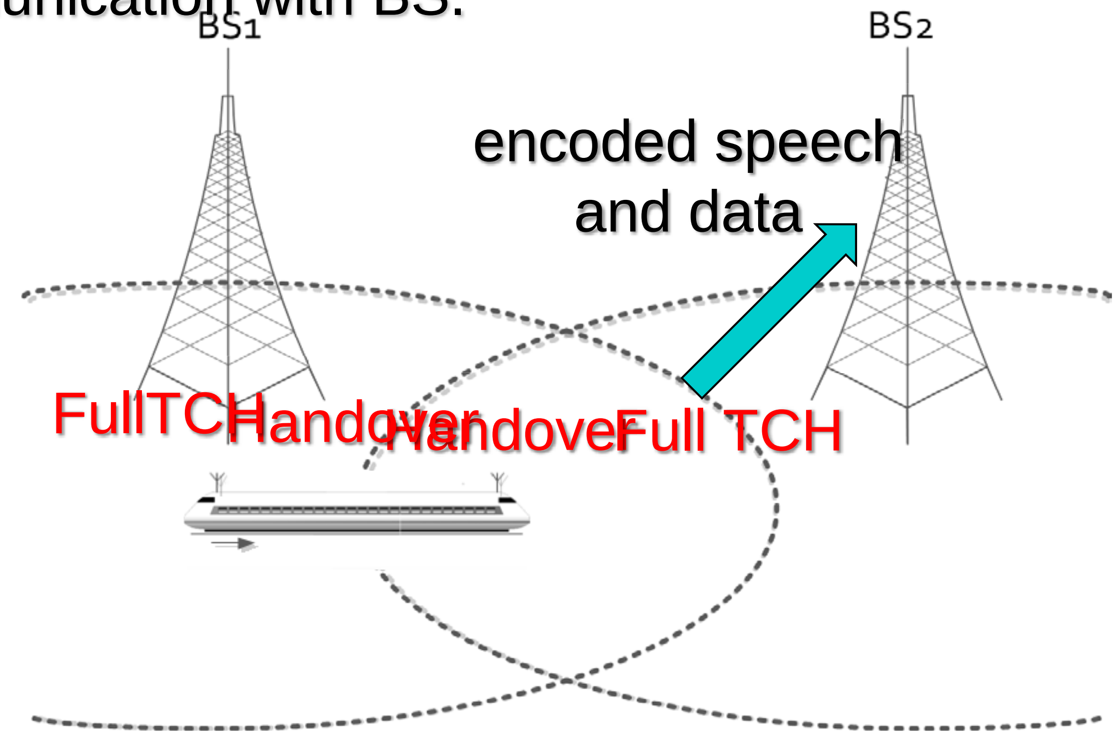
# Handover process 2

- Handover is triggered by the measurement report of A1.
- During the handover process, A1 should activate 2 Full TCHs and 1 Hybrid TCH in BS2.
- A2 keeps communication with BS1 during the whole process.



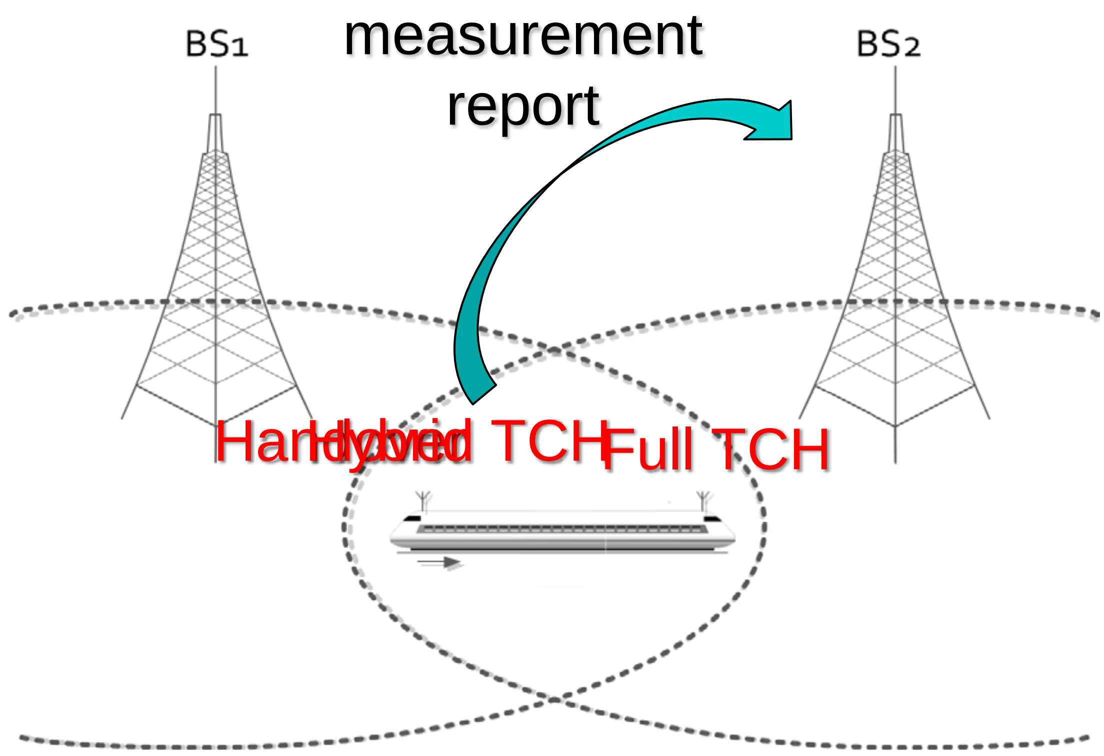
# Handover process 3

- A1 connects to Full TCH in BS2 after handover process 2.
- BS1 then triggers the handover process of A2 automatically.
- Meanwhile A1 connects to Full TCH and takes charge of the communication with BS.



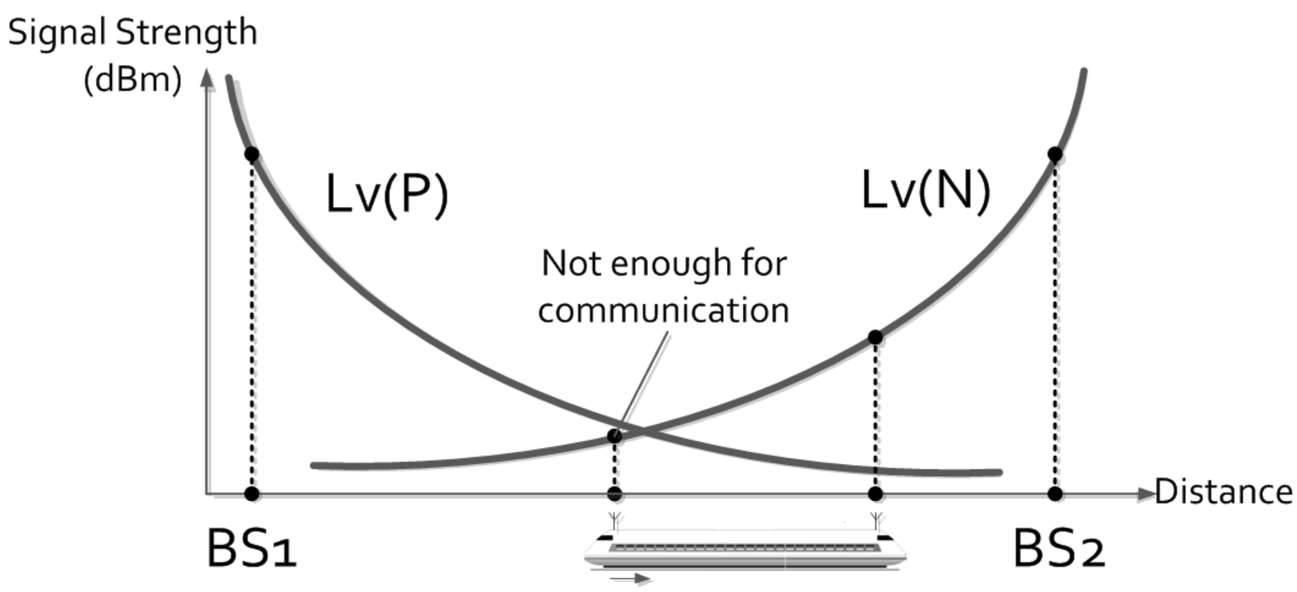
# Handover process 4

- A2 directly connects to Hybrid TCH after handover process 3.



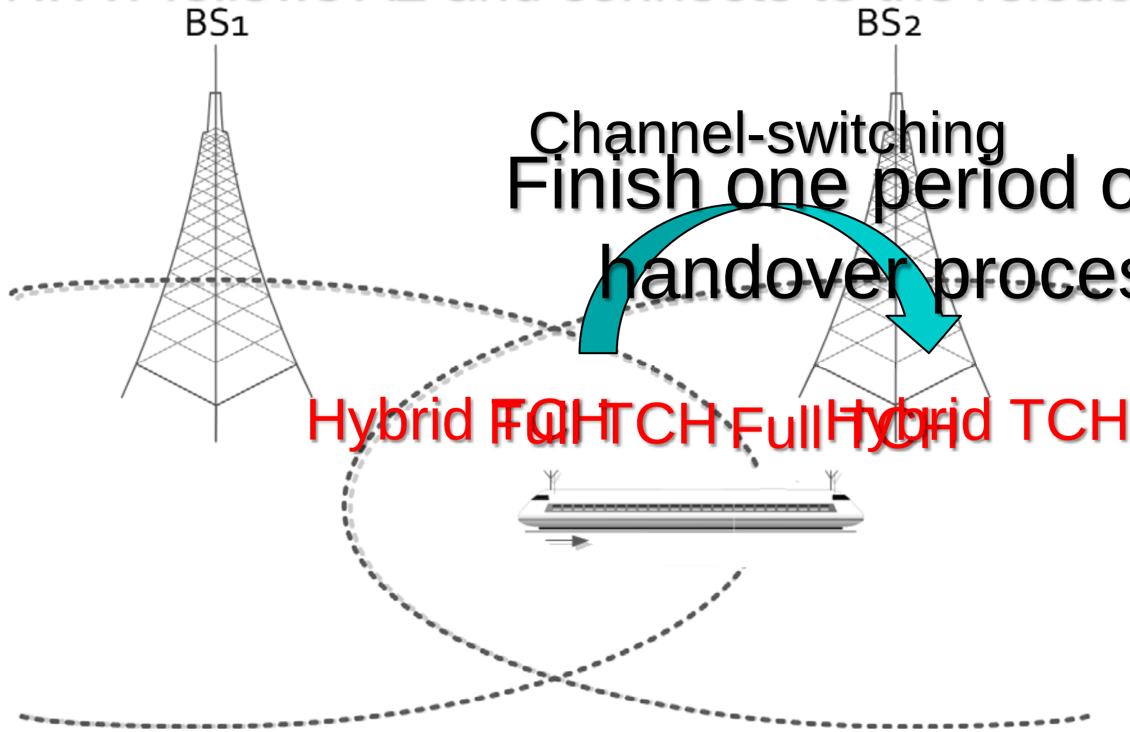
# Handover process 4

- Considering that A2 may not receive enough power to communicate with BS when it finishes handover, so it starts to send measurement report to BS2 so that BS2 could determine whether its signal strength is adequate for communication.



# Handover process 5

- Measurement report transmitted by A2 will trigger another ***channel-switching*** process.
  - ✓ A2 connects to the additional Full TCH and release Hybrid TCH. A1 follows A2 and connects to the released Hybrid TCH.



# Insight analysis

- Consider the handover of A1.
  - ✓ Measurement report is sent more quickly, latency incurred in measurement procedure is effectively.
  - ✓ After handover, A1 could be directly used for transmitting encoded speech and data.

- Consider the handover of A2.
  - ✓ It does not need measurement and triggering procedure.
  - ✓ Its channel is pre-activated by A1.
  - ✓ The handover is completed very quickly within 1 second.

# Insight analysis

- There are two kinds of measurement report within the proposed scheme.
  - ✓ The first kind is sent by A1 which is used for BS to determine whether to trigger the handover of A1.
  - ✓ The second kind is sent by A2 which is used for BS to determine whether the power level received by A2 is adequate for communication.
  - ✓ The basic assumption in our scheme could guarantee that BS identify and distinguish these two kinds of measurement report.

# Insight analysis

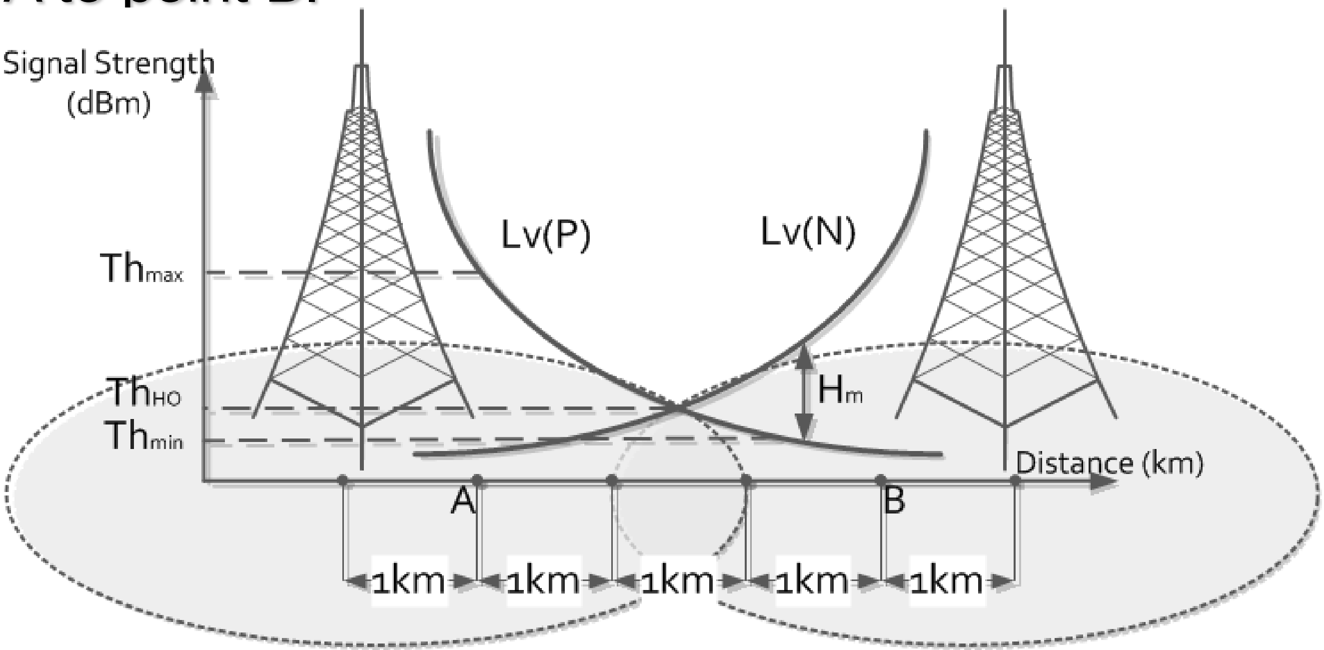
- To sum up, we can see that the main differences between the proposed scheme and the conventional one.
  - ✓ After the modulation of TCH, measurement report is sent more quickly.
  - ✓ Dual-antenna system collaborates with BS to complete handover.
  - ✓ At any time during the handover process, at least one antenna can be used to transmit encoded speech or data and therefore achieve seamless handover.

# Outline

- Introduction
- Traditional Handover Scheme
- Dual-antenna Handover Scheme
- **Simulation and Performance Analysis**
  - Simulation model
  - Results and performance analysis
- Conclusion

# Simulation model

- We build up the simulation model for the proposed scheme [2] and simulates the handover process when the train moves from point A to point B.




Handover scenario


[2] M. N. Halgamuge, H. L. Vu,K. Ramamohanarao, and M. Zukerman, ”A Call Quality Performance Measure for Handoff Algorithms,” International Journal of Communication Systems, vol. 24, no. 03, pp. 363-383, March 2011.

# Simulation model

- When conducting the simulation, we generate signal strengths at each point along the path from A to B.
- For a realistic view, the simulation follows the Hata Model for path loss calculation and we also add shadowing effect into consideration [3].

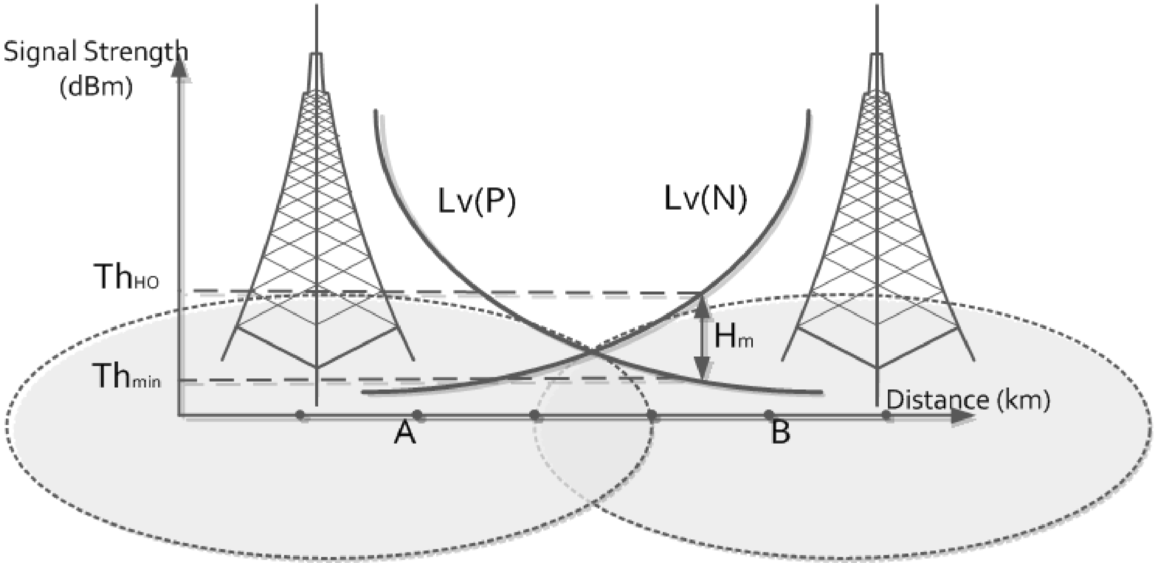
$$L(d) = -75 - 35\log_{10} d + \varepsilon$$

where $\varepsilon \sim N(0, 8dB)$ .

[3] M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Radio Services," IEEE Transactions on Vehicular Technology, vol. 29, No. 3, pp. 317-325, August 1980.

# Simulation model

- We adopt three handover methods in the simulation.




*Threshold* method

$$\begin{cases} Th_{min} < Lv(P) < Th_{HO} \\ Lv(P) < Lv(N) \end{cases}$$

*Hysteresis* method

$$Lv(N) - Lv(P) = Hm$$

*Threshold with Hysteresis* method

$$\begin{cases} Lv(P) < Th_{HO} \\ Lv(N) - Lv(P) = Hm \end{cases}$$

# Simulation model

- Latency incurred in the handover of A1:

$$T_h = 4 \times \tau_m + 1.358s$$

where $\tau_m = 0.48/n$, $n$ is the number of of SACCH in Hybrid TCH.

- Latency incurred in the handover of A2:

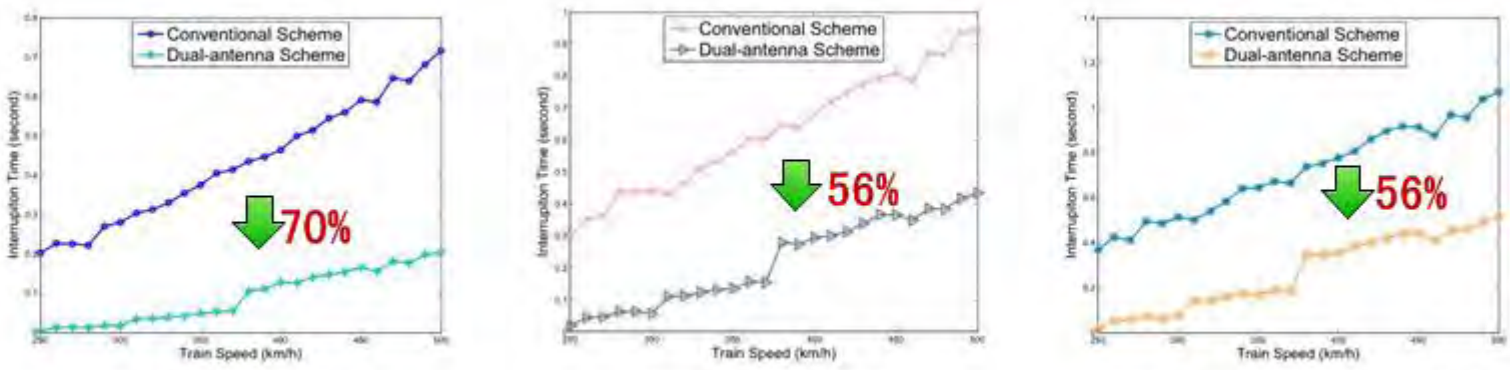
$$T_h = 0.441s$$

# Results and performance analysis

- We simulate the handover process of a train for 1000 times, and each time the speed of the train ranges from 250km/h to 500km/h.
- Signal strengths at each point along the path has been determined by the simulation model and therefore handover of A1 and A2 could be triggered and performed according to the ***three handover methods*** with different $n$ .
- After each simulation we calculate two important indexes, ***interruption time*** and ***call dropping rate***, to evaluate the performance of the proposed scheme.

# Results and performance analysis

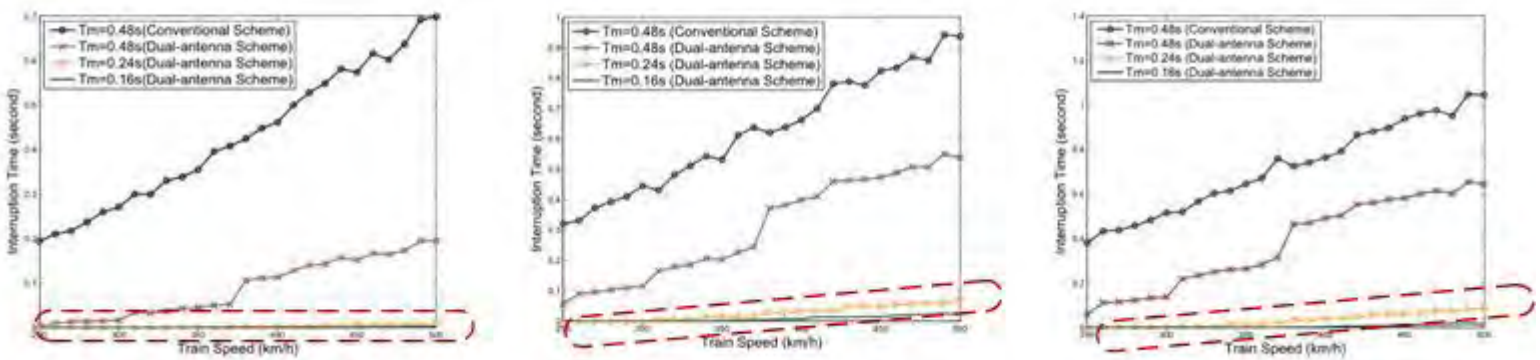
- Results show that the proposed scheme could effectively reduce ***interruption time*** by at least 50%.




(a) Threshold Method (b) Hysteresis Method (c) Threshold+Hysteresis Method

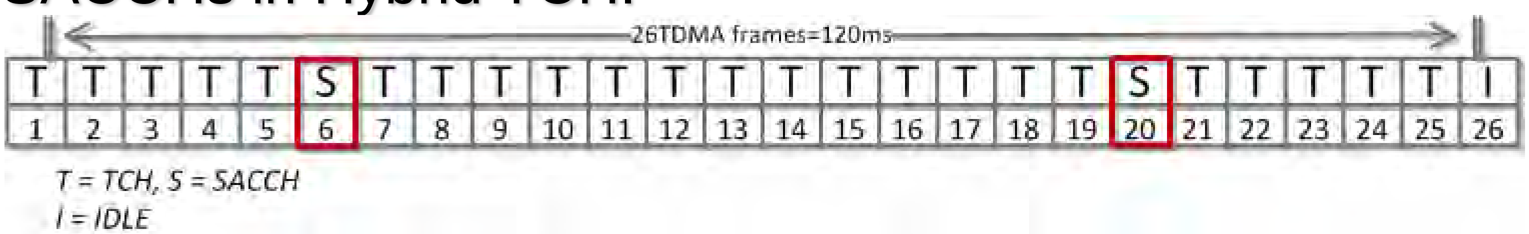
# Results and performance analysis

- Impact of different $\tau_m$ on ***interruption time.***



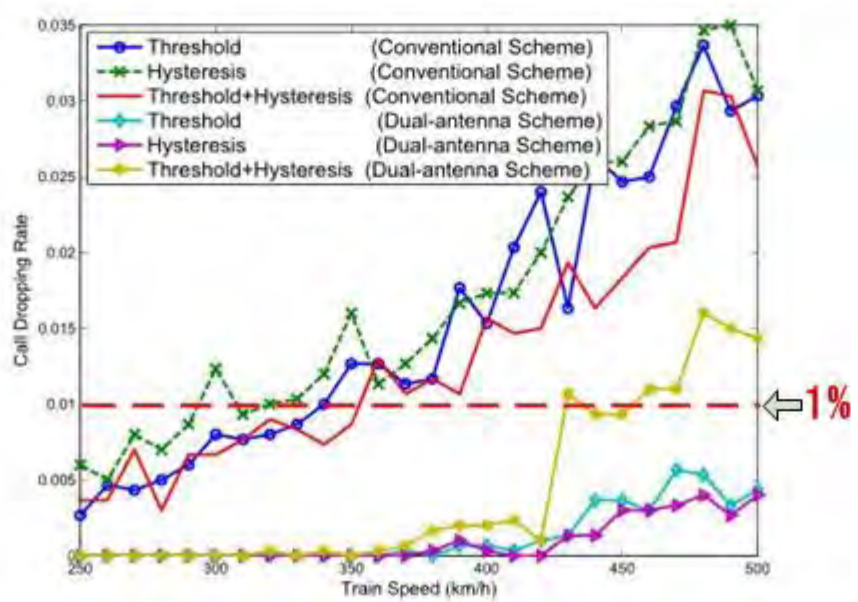

(a) Threshold Method (b) Hysteresis Method (c) Threshold+Hysteresis Method

- In our scheme we choose 0.24s as the suitable $\tau_m$ , i.e. there are 2 SACCHs in Hybrid TCH.



# Results and performance analysis

- According to specification in GSM network, call dropping rate should be within 1%. Results show that when the train speed is beyond 300km/h, call dropping rate obviously exceeds 1% for conventional scheme. However in the proposed scheme call dropping rate remains within 1% even train speed reaches 450km/h.



# Results and performance analysis

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

- To sum up:
  - The proposed dual-antenna handover scheme could effectively reduce interruption time and guarantee lower call dropping rate, therefore provides better service quality.
  - We also determine the suitable $\tau_m$ to help the system achieve better performance.

# Outline

- Introduction
- Traditional Handover Scheme
- Dual-antenna Handover Scheme
- Simulation and Performance Analysis
- **Conclusion**

# Conclusion

- In this paper, we have proposed a novel handover scheme based on dual-antenna system for GSM-R network.
  - ✓ We use 2 functional TCH so that the dual-antenna system could collaborate and achieve seamless handover.
  - ✓ Through simulation and performance analysis we prove that the proposed handover scheme is effective in high-speed scenario.
  - ✓ Therefore the proposed dual-antenna handover scheme guarantees better service quality in GSM-R network.

# Thank you for listening