MORA Routing and Capacity Building in Disruption-Tolerant Networks

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DTN

- mobile ad hoc wireless network
- end-to-end routing
- depends on the number of participants, their storage capacity, communication and movement patterns
- paper: focus is on performance

Goal

- improve performance by using MORA(=Multi-Objective Robotic Assistance)

MORA

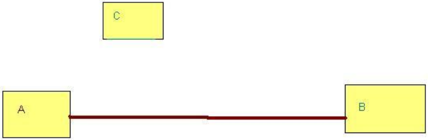
- autonomus agents to balance the network demand

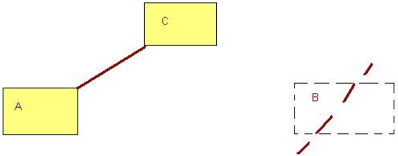
- adapt the motion of the agents to bandwidth and latency

Communication

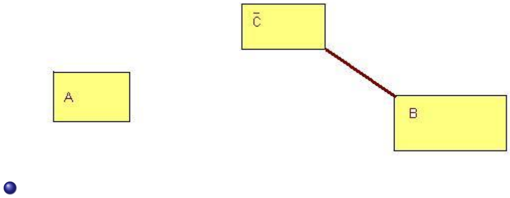
- end to end communication
- mobile nodes
- nodes store and pass

Communication

- 

- 

Communication



Routing

routing algorithm "Drop-Least Encountered"

- estimate the distance by Likelihood
- peer = 0
- exchange by meeting
- peer=1 and send
- values sink by time and increas by frequently meetings

optimal motion of an agent

- NP hard
- reduce "dial-a-ride problem" a Traveling-Salesman-Problem
- a graph and the peers present participants
- message from A to B
- agent transfer if there is no communication

Multi-objective Control

to get optimzed motion in praxis

- multi-objective control methods
- generate complex behavior by put together simple
- controller present the behavoir with a control function

Control methods

Subsumption:

- include one or more controllers per layer
- status information and can give commands
- Higher level controller can grap status information of lower controller and overwrite their commands

Control methods

Nullspace:

- concurent execution of multiple controllers
- hierarchy
- lower-level controller have no effect of higher-level
- consists of all vectors x so that Ax=0
- collection of control commands

Nullspace example

- point p=(x/y)
- controller $\phi 1$ changing state to achieve x=0
- controller $\phi 2$ changing state to achieve y=0
- controller $\phi 2$ orthogonal
- controller $\phi 2$ operates in nullspace of controller $\phi 1$

At each level of hierachy the controller optimizes its action in nullspace of higher controllers

Performance Metrics

- Bandwidth
- Unique Bandwidth
- Message Latency
- Peer Latency

Performance Metrics

Bandwidth:

- total number of messages at a point in time
- schedule motion of agents to increase bandwidth
- space of transfer message should be used effectively
- agents have to consider their travel time for delivery

Performance Metrics

Unique Bandwidth:

- total number of unique messages which are currently active
- bandwidth should be used effectively
- agents should transmit messages not already in transmit

Performance Metrics

Message Latency:

- average amount for a message delivery
- for reducing agents should move towards peers which are sending or receiving many messages

Peer Latency:

- average time since a peer was last visited by agent
- participants should be visited intermittently

Distributed Network State Maintance

- real network no global information available
- each peer has information about their own state
- all participants should have synchronized clocks
- each agent have information about participants
- two agents meet and exchange packages and routing protocol

Movement Controllers for Performance Metrics

- Total Bandwidth Controller ϕ T
- Unique Bandwidth Controller ϕ U
- Message Latency Controllerϕ D
- Peer Latency Controller ϕ p

Movement Controllers for Performance Metrics

Total Bandwidth Controller ϕ T:

- the choosen peer has the largest number of messages not seen by agent

Unique Bandwidth Controller ϕ U:

- choose peer which have the largest number of messages not present

Message Latency Controller ϕ D:

- choose peer whose average delivery time is the largest

Peer Latency Controller ϕ p:

- choose location n_i (last visited)
- $\Delta\ t_{n_i}$ time since n_i has been visited
- $n = argmin_{n_i}\ \Delta\ t_{n_i} + t_{n_i}$

Movement Controllers for Performance Metrics

- these controllers consider only a single performance metric
- generate conflicts for agents
- for example
  - two peers with a large number of messages
  - Total Bandwidth Controller ϕT only maximize these peers
  - other peers wouldn't be visited
  - not possible to combine bandwdith and latency controller
  - solution: coordinate controllers and select parameters

Multi-Objective Control

hierarchy

- ϕ p $<$ ϕ D $<$ ϕ U $<$ ϕ T
- ϕ i $<$ ϕ j means j more important than i
- example Subsumption:

example Subsumption:

- Controller with highest priority decides
- lower priority get only a chance if all higher optimized their metric
- Controller ϕT optimize its bandwidth and give the next lower controller ϕU a chance
- if ϕ U violated the total bandwidth ϕ T get the control back

Comparison of Nullspace and Subsumption

- nullspace controller execute concurrently and subsumption at a time
- low nullspace controller can't influence higher controller

Experimental Evalution

based on

- DTN
- 30 buses
- GPS devices on each bus
- location of each bus available

Experimental Evalution

trace generator

- use GPS to reconstruct movement and timing of 9 buses routes in area of 8.24 km
- each route is pesented by trace days
- advantage: buses can be varied

Experimental Evalution

default values for each simulation:

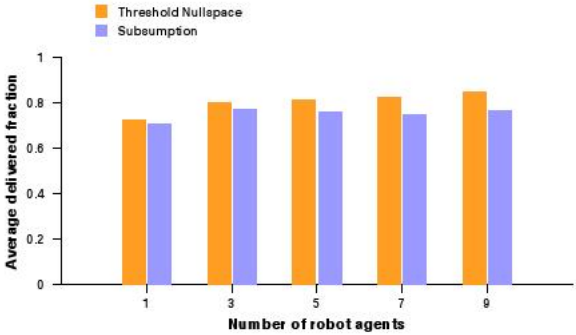
- unlimited buffer
- load of 36 pkts/hour
- 10-Kbyte packets
- 9 buses, each on distinct routes
- agents increase the buffersource, so random choice 3 buses without free storage capacity

Experimental Evalution

Protocols:

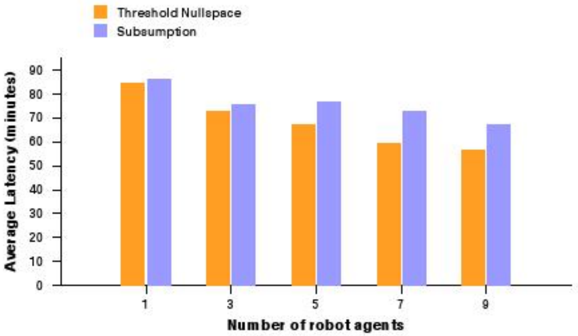
- Random: first packets to B and the rest by chance
- MaxProp: Each packet get a number, the packet with the lowest number is send first
- ME/DLE : packets get priority, lowest first
- FIFO : First in First out

Comparing Supsumption and Nullspace:

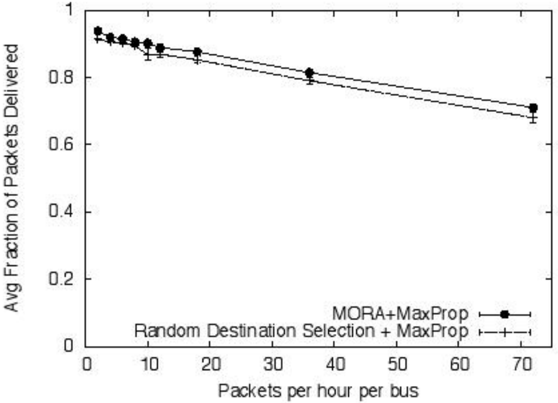


Experimental Evalution

Comparing Supsumption and Nullspace:



Comparison of MORA to movement using random selection



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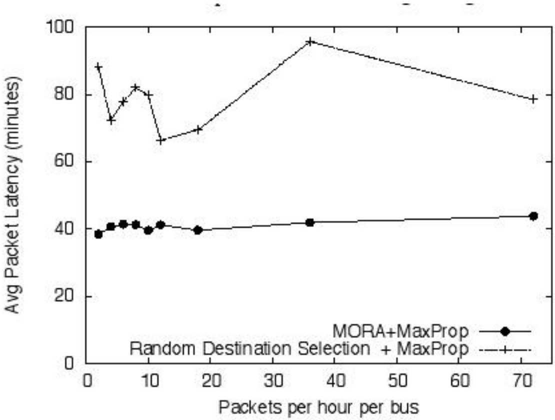
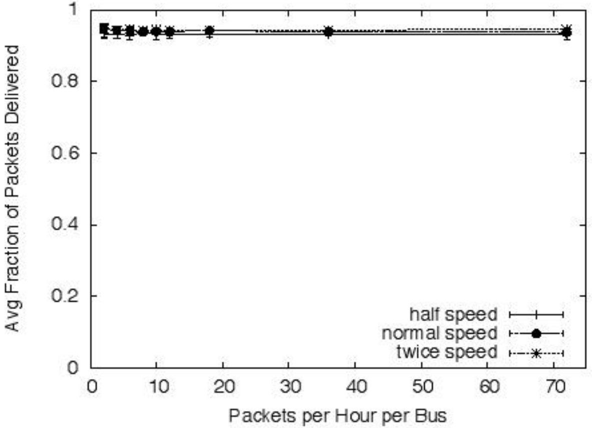


Comparison of MORA+MaxProp by varied speeds of agents



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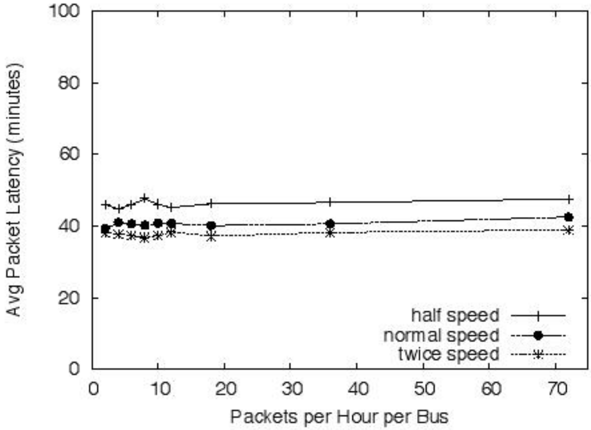
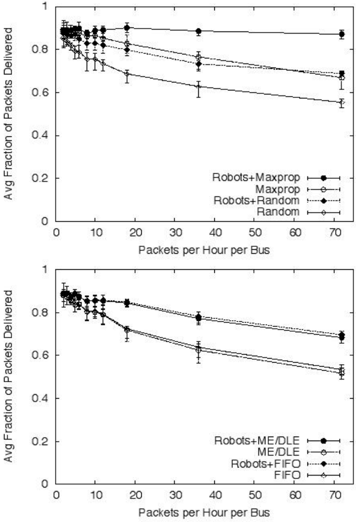


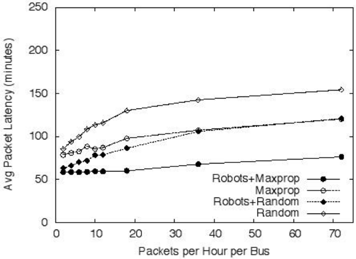
Experimental Evalution

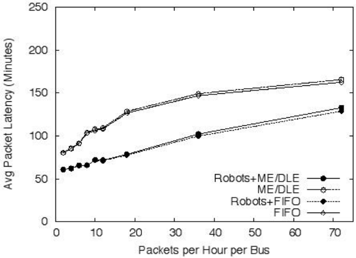
packet delivery rate as network load increases



Experimental Evalution

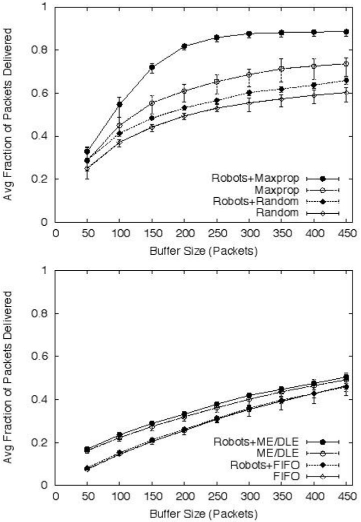
packet latency as network load increases





Experimental Evalution

packet delivery rate as local buffer size increase



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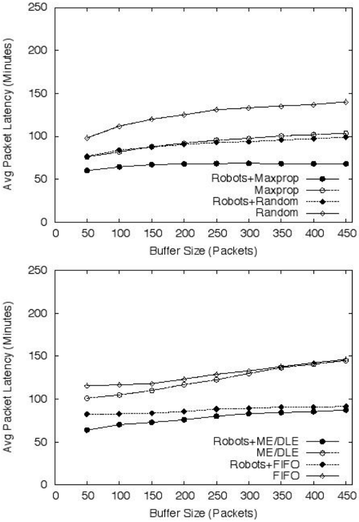
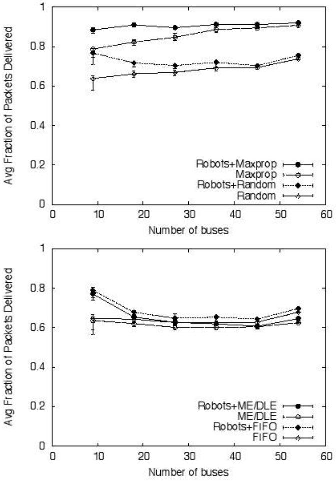
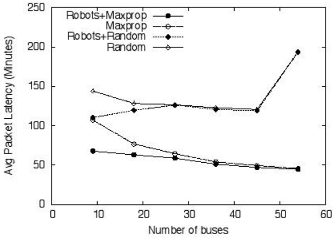
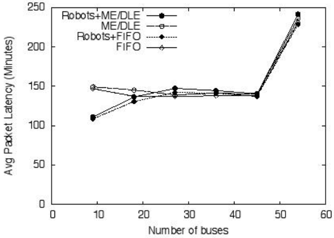


packet delivery rate with an increasing number of buses



packet latency with an increasing number of buses





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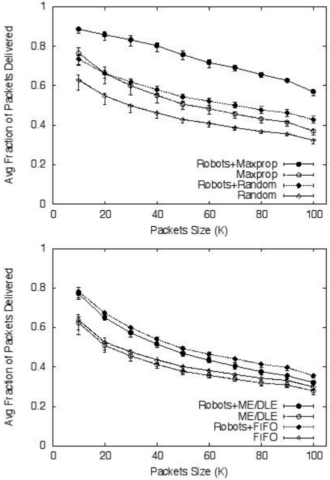

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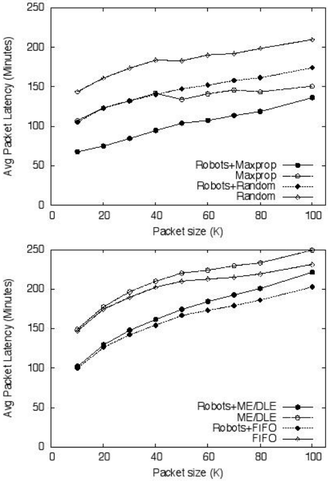
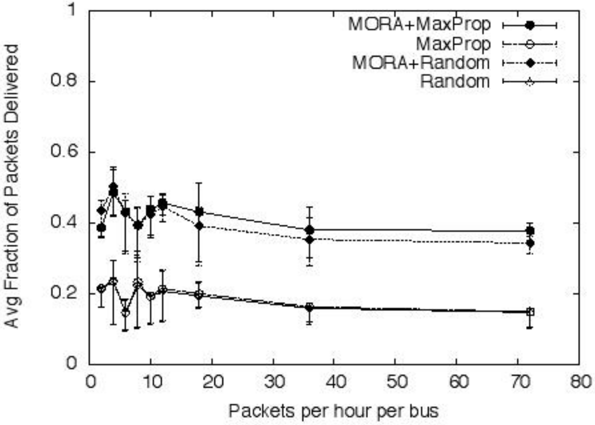
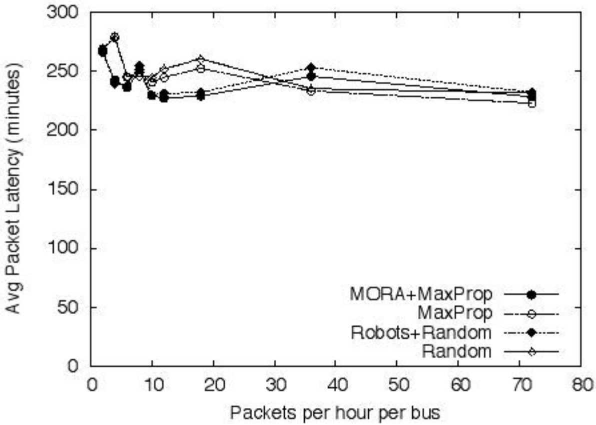


Synthetic mobility model: delivery rate as packet load increases

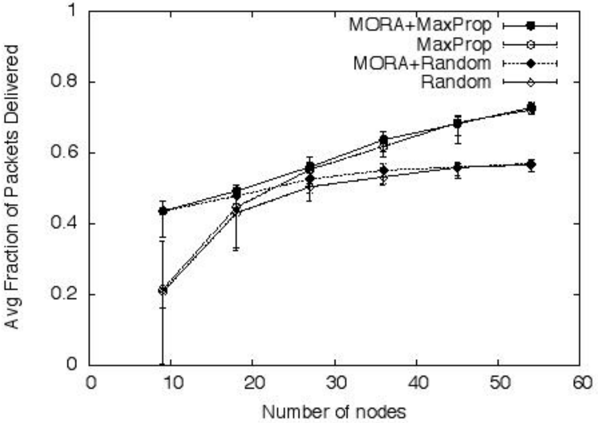


Synthetic mobility model: latency as packet load increases



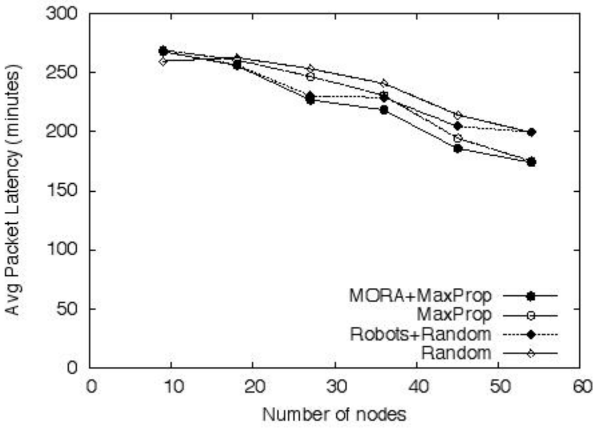
Experimental Evalution

Synthetic mobility model: delivery rate as number of nodes inceases



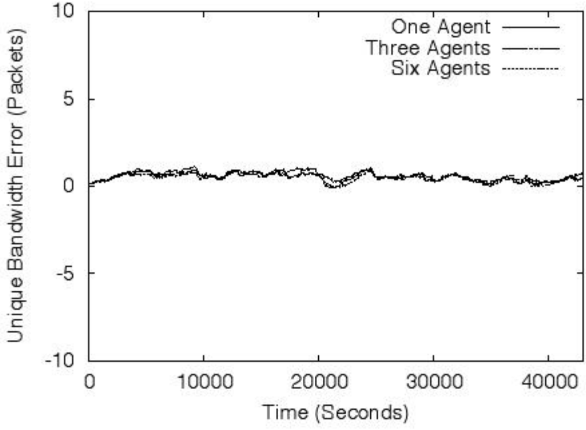
Experimental Evalution

Synthetic mobility model: latency as number of nodes inceases



Experimental Evalution

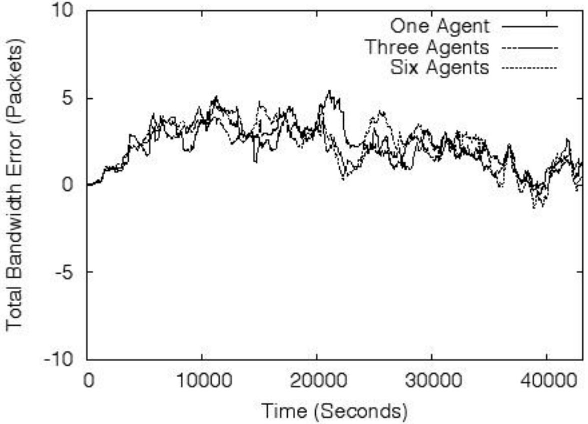
Bandwidth error



(a) Bandwidth Error

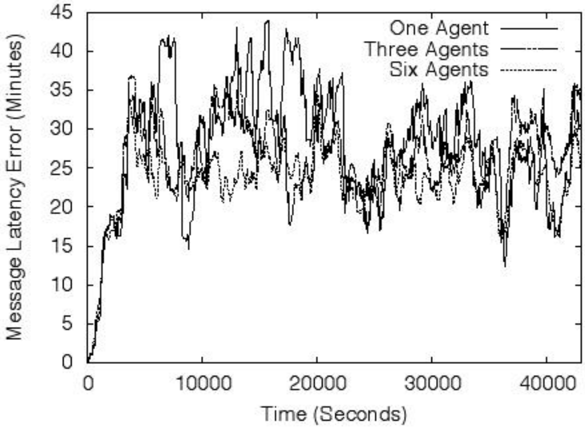
Experimental Evalution

Bandwidth error



(b) Bandwidth Error

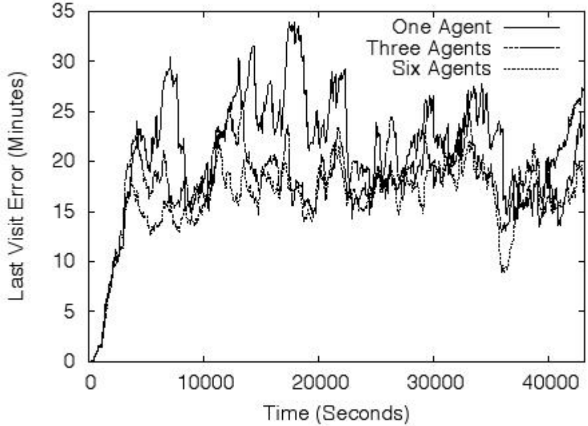
latency error



(c) Latency Error

Experimental Evalution

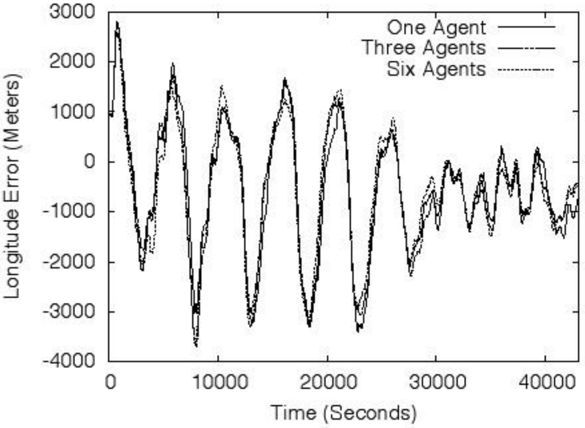
latency error



(d) Last Visited Error

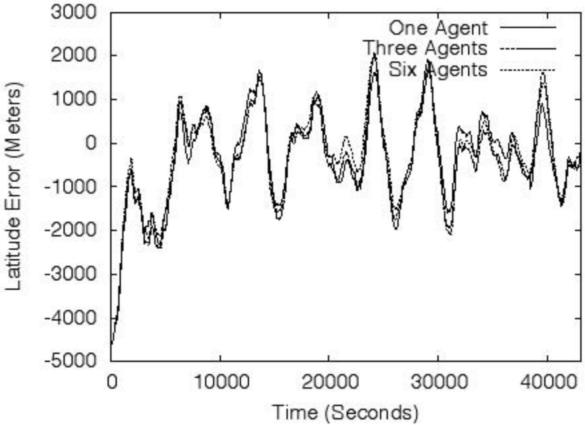
Experimental Evalution

Agent longitude error



(e) Agent Longitude Error

Agent longitude error



(f) Agent Latitude Error

Conclusion

- To improve the performance of DTN use MORA
- MORA sets autonomous agents in the DTN
- To get the optimize movement use control methods

The End

Thank you for your attention