TRAILS Mobility model

Implementation and Performance analysis

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- Several researchers agree that a mobility model that does not capture the interaction of targeted users would give misleading results in the simulation of OppNets.
- Therefore, I present TRAILS as fully scalable model capable to represent real scenarios in a reasonable way.

TRAce-based ProbabILiStic Mobility Model

- TRAILS is a mobility model in which a user performs movements extracted from recorded traces, but it chooses the destinations randomly

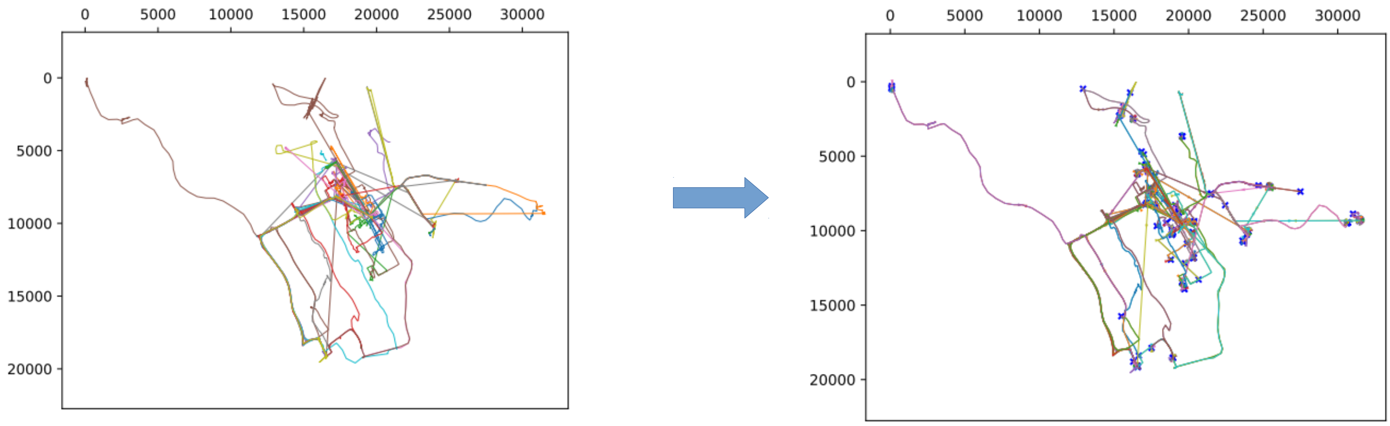
-TRAILS can be simulated with a larger number of users and for a longer time than the original traces. Therefore, TRAILS is a full scalable, and flexible mobility model.

TRAILS requirements

- Traces from a real scenario
- Graph generator
- Model Simulator

-To be able to use TRAILS we need {Slide requirements}
-In this presentation I am going to explain how the generator and the simulator work.
-Additionally I am going to present results of simulating traces of 4 different real scenarios and their corresponding TRAILS graphs.
-Finally I will present a recommendation to improve the performance of TRAILS

Graph generator

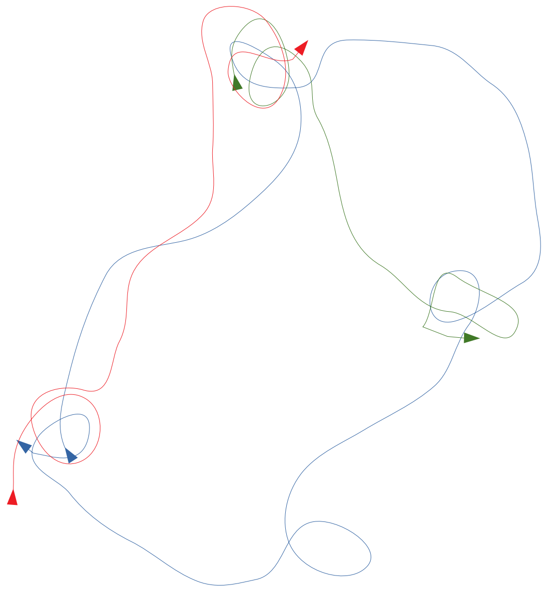


-A user in TRAILS moves to a random destination, It stays in that destination a random time and then it moves to another random destination.

-The destinations are called POI and the trajectories used by a user to move between destinations are called Links.

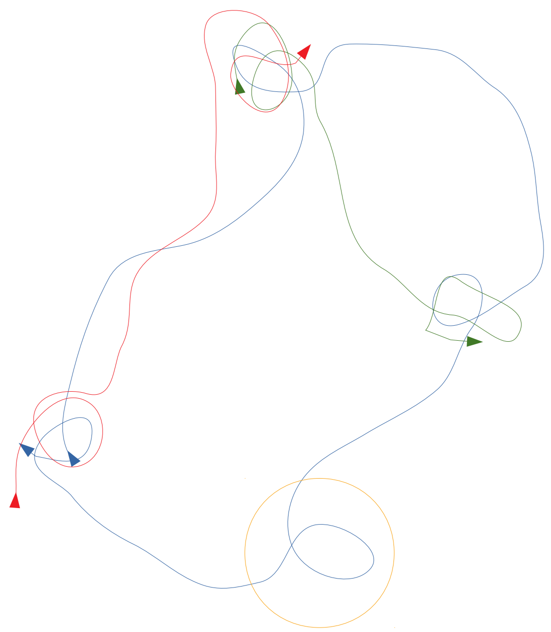
-POIs and Links are extracted from real traces with a graph Generator

Find Points of Interest

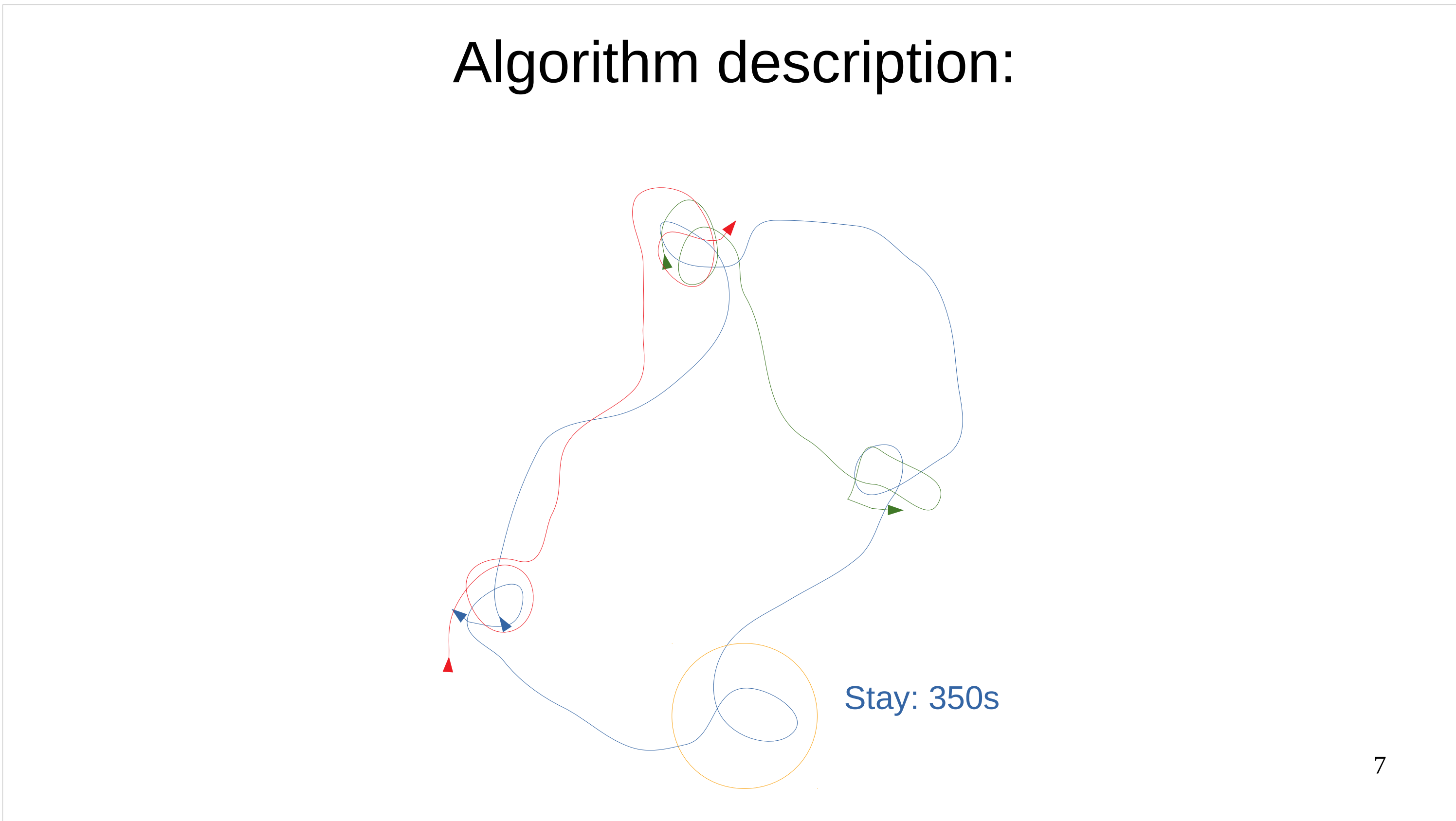


-In this figure we have a trace of 3 users.
-And we need to find the POIs
-A POI is a place in which the users spend most of their time
-A POI is limited by a fixed diameter for example 30m, and it has a list of time intervals in which each time is bigger than threshold for example 5 minutes
-The next slides describe the process used to find POIs.

Algorithm description:

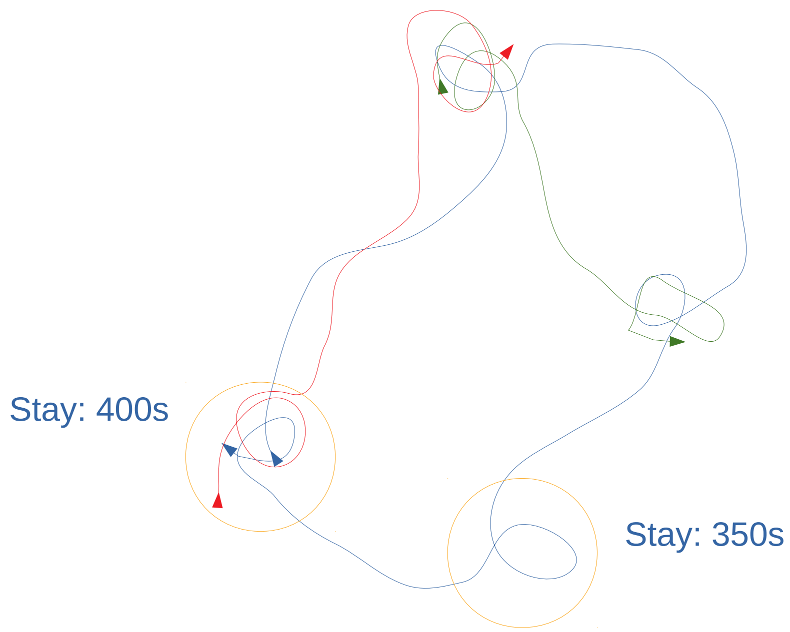


-First, by using the smallest enclosing circle algorithm proposed by Emo Welz in its paper “*Smallest enclosing disks*”, we search a set of consecutive trace-points enclosed by a circle smaller than a threshold. For example 30 meters



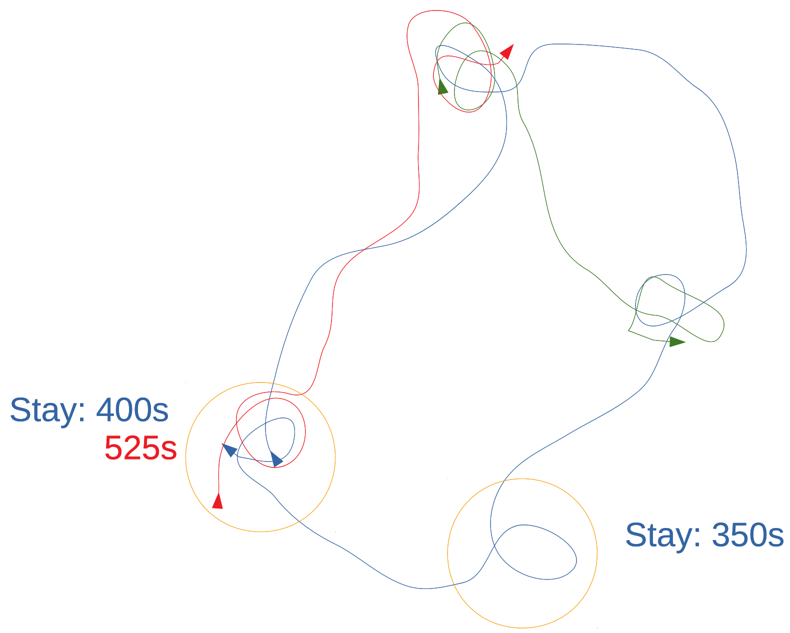
-We compute the time that the user stayed inside the enclosing circle.
-If the time is bigger than threshold, for example 5 minutes, we create a POI and we add the time to a list.

Algorithm description:



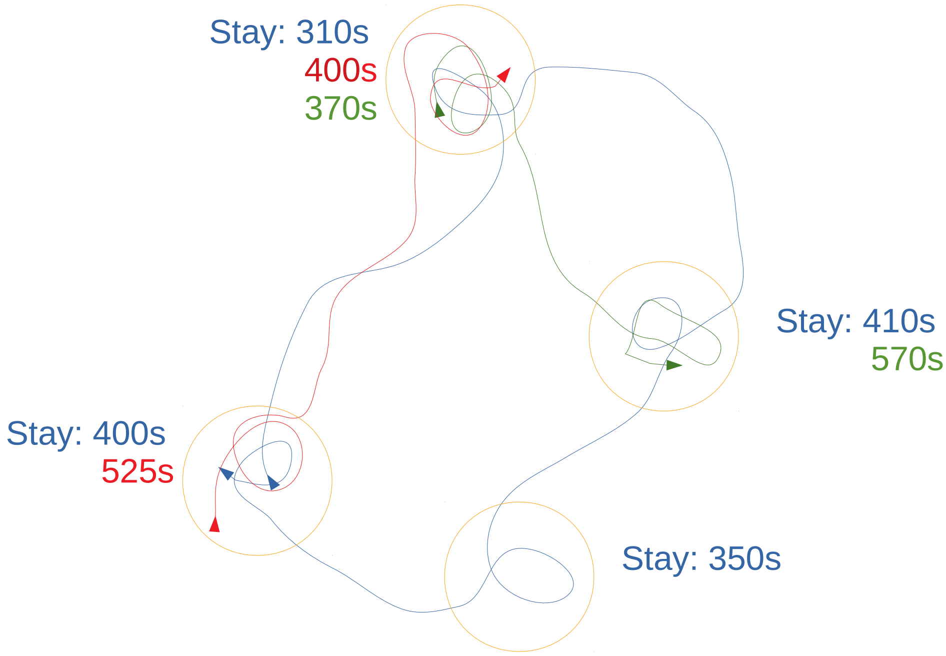
-We repeat the process until we find a new POI.
-Then, we check there is no other user spending a time interval bigger than 5 min inside the POI

Algorithm description:



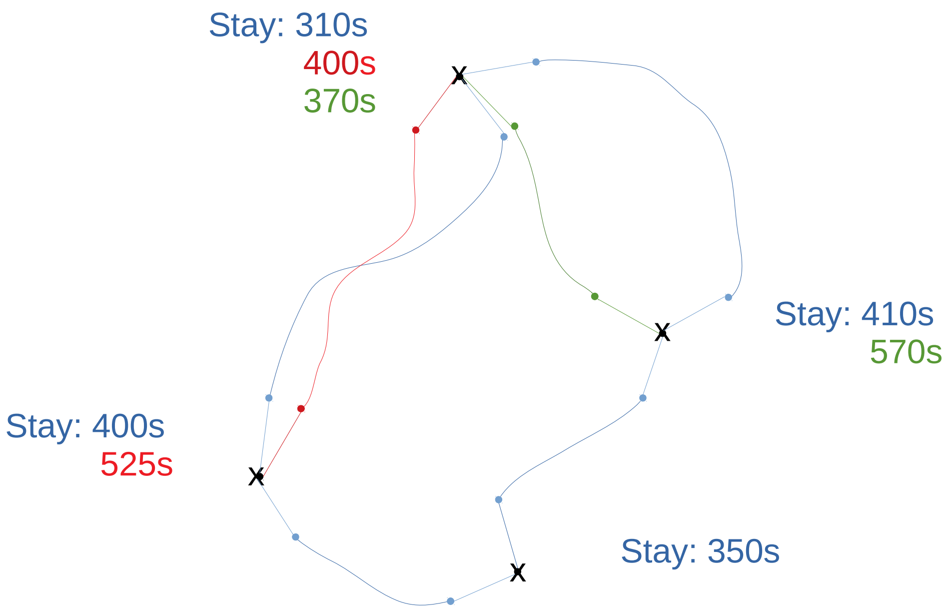
If there is another user spending time inside the POI we add the time interval to the a list of the POI

Algorithm description:



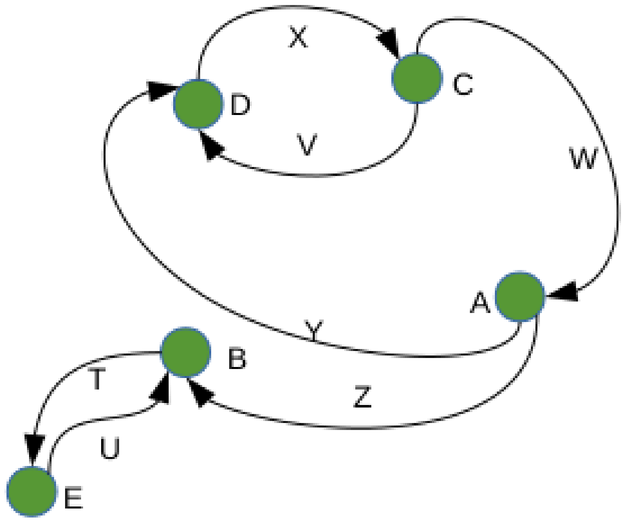
We repeat the process until we find all the POIs in the graph

Algorithm description:



For each POI we replace all the points inside the enclosing circle by a single point at the center of the circle

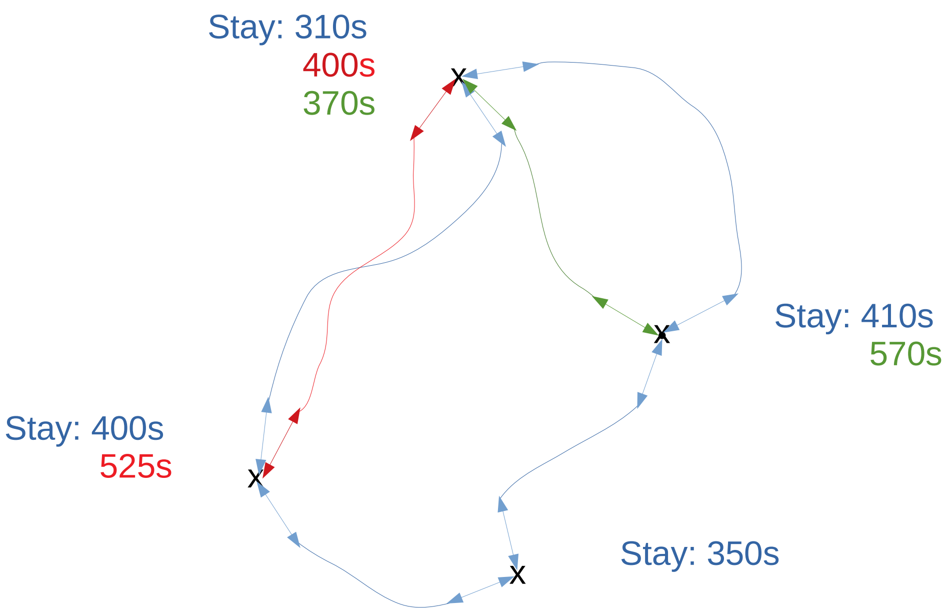
Find links



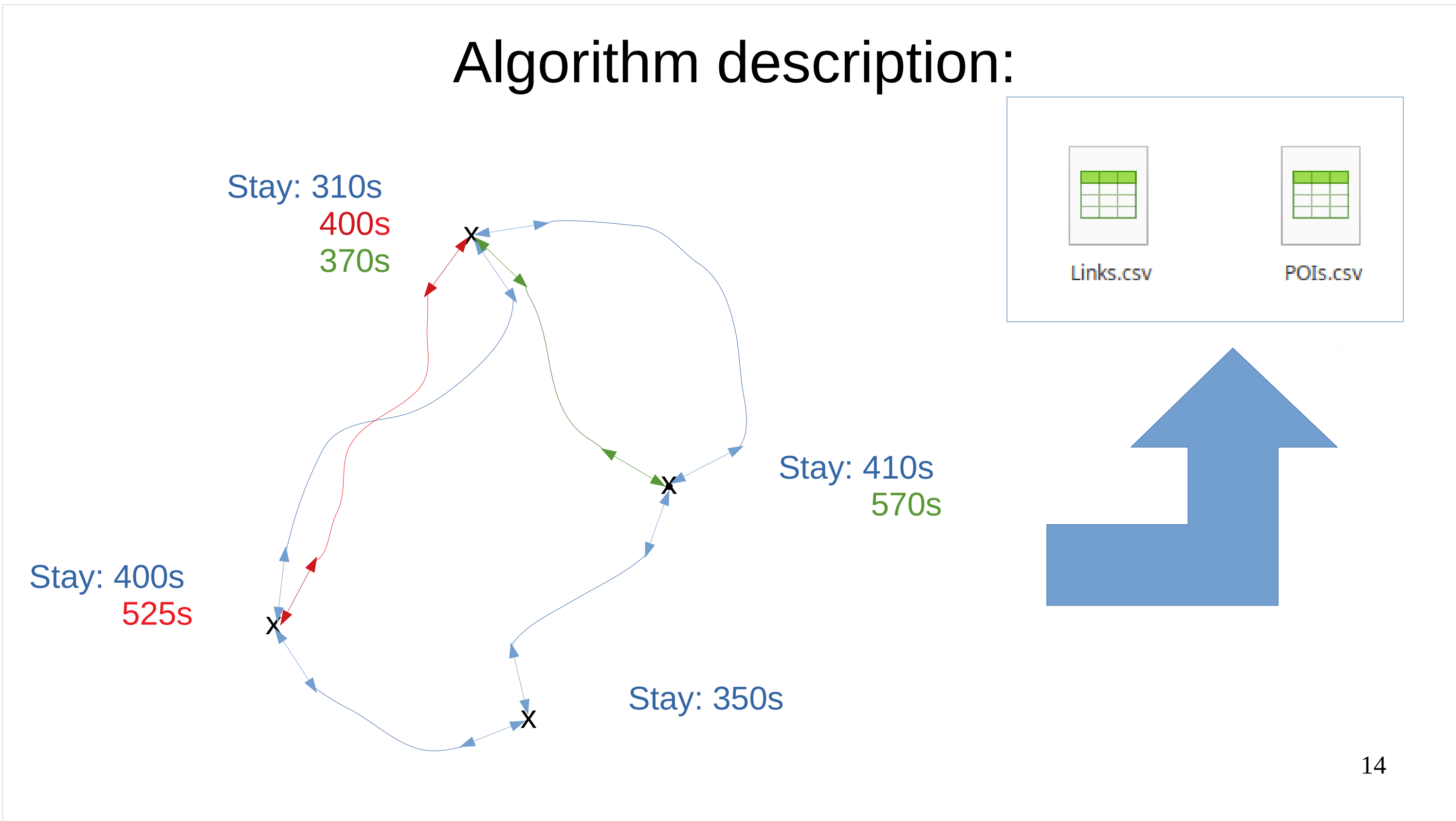
-If we connect the POIs with the Link from the traces as shown in the figure, we would have a problem for example if a user travels from A to B it would never go back to A. In other words, if we simulate this graph long enough all users would end up between B an E.

-To solve this problem we can remove link Z, make link Z bidirectional or make all links bidirectional.

Algorithm description:

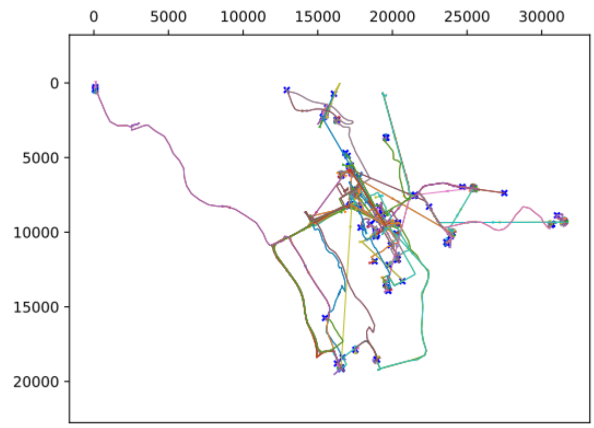


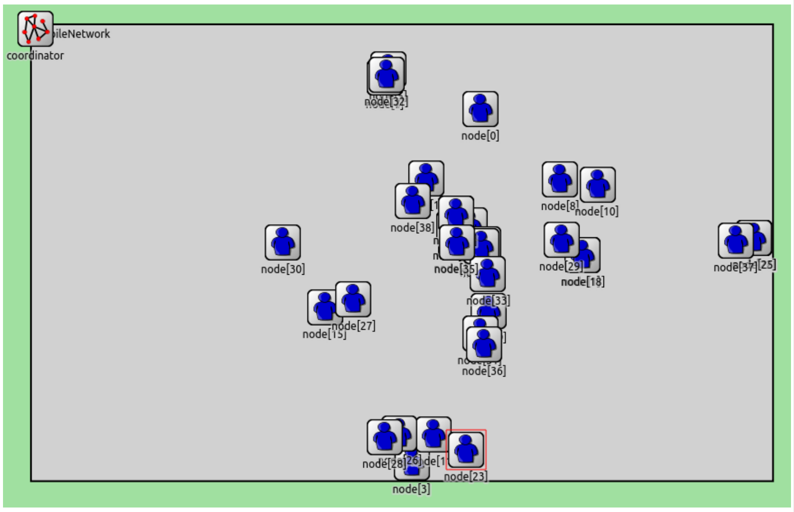
For further analisis we make all links bidirirectional. Nonetheless, the implemented graph generator is capable to execute any of the 3 solutions.



Finally we export the POIs and the links to 2 CSV files in order to use them in a simulator as a TRAILS graph.

TRAILS simulator





-The model simulator reproduces user's movements according to a TRAILS model by using a set of rules in combination with a TRAILS graph.

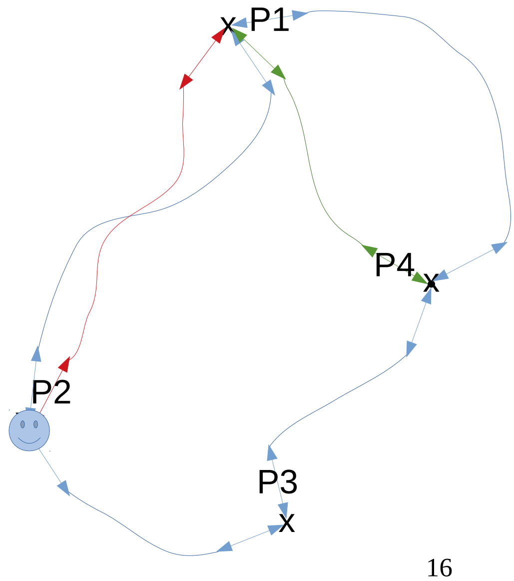
-In the simulator there are mobile users and a coordinator module.

-The coordinator loads the TRAILS graph and it shares the information that each user needs on order to move according the TRAILS model.

-The next slides describe how the model in the simulator works.

Algorithm description:

POI	Coordinates	Stay times	Links	Next POI
P1	583;324	400	L1	P4
		310	L2	P4
		370	L3	P2
			L4	P2
POI	**Coordinates**	**Stay times**		
P2	246;820	400	L6	P1
		525	L7	P1
			L8	P3
POI	**Coordinates**	**Stay times**	**Links**	
P3	678;919	350	L9	P4
			L10	P2
POI	**Coordinates**	**Stay times**	**Links**	
P4	743;512	410	L11	P1
		570	L12	P1
			L13	P3



- Once the POIs and links are loaded in the coordinator, the coordinator assigns a random POI to each mobile user

Algorithm description:

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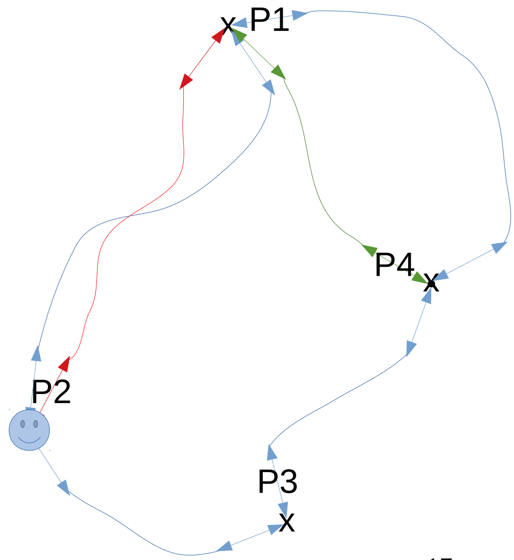

- -When all users are in theirs initial position. The coordinator sends a link and a stay time, chose randomly.
- -Then the user waits in its position for a time interval equal to the stay time
- -Finally the user follows the link until it arrives to its next POI

Algorithm description:

POI	Coordinates	Stay times	Links	Next POI
P1	583;324	400	L1	P4
		310	L2	P4
		370	L3	P2
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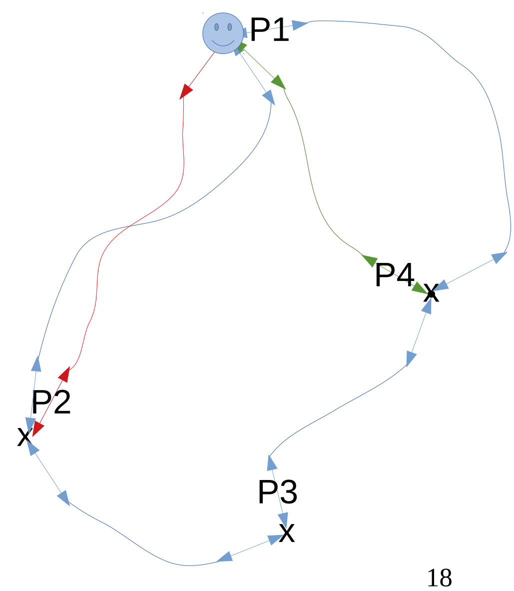


- When a user arrives to its next POI, it sends the index of the POI to the coordinator.
- And the coordinator sends back a new stay time and link randomly chosen.
- And the cycle is repeated.

-Is it can be observed the model is not limited by a fixed number of users or a fixed simulation time.

Results & Conclusions

-We simulated TRAILS and traces and then we used statistical tests to observe the relation of TRAILS with real scenarios.

TRAILS vs Traces

Metrics

1. Contact duration between nodes (**CDBN**)
2. Contact probability (**CNPR**)
3. Number of of contacts between nodes (**NCBN**)
4. Number of of contacts between the same pair of nodes (**NCBS**)
5. Contact time between nodes (**CTBN**) (Intercontact)

Scenarios

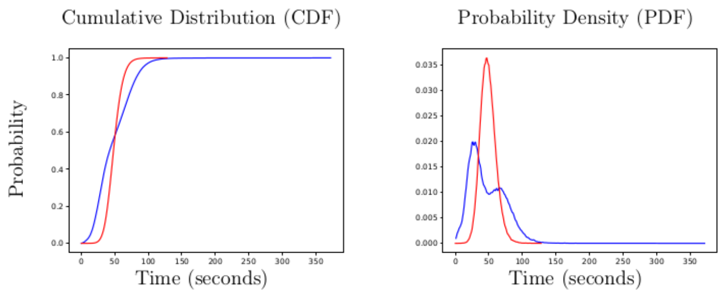
Name	Area Km^2	Time Hours	Users
San Francisco	7145.486	575.425	536
Rome	10238.67	720	315
New York	618.699	22.658	39
Orlando	276.592	14.283	41

The performance of OppNets depend on the interaction between users. Therefore, we use the following metrics to compare sample distributions of TRAILS and traces.

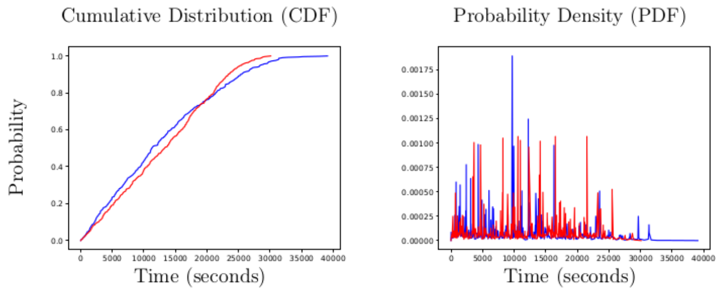
CDBN it is the time interval when two users are in contact. In other words, being at a distance smaller than 30m.
CNPR it is the estimation of the probability of two nodes being in contact.
NCBN it is the total number of times that each user was in contact with another user.
NCBS it is the total number of times that a pair of users were in contact.
CTBN it is the time interval between the last contact and a new contact of a user (intercontact).

In order to avoid biased conclusions we used 4 different scenarios

San Francisco



NCBS of TRAILS (red) and traces (blue) of 536 taxis in San Francisco



NCBN of TRAILS (red) and traces (blue) of 536 taxis in San Francisco

-By only looking at the sample distributions is difficult to know how different is TRAILS from traces. The only thing that we can conclude from the plots is that the samples are no normally distributed.

-Therefore, we need to perform a statistical test to the metrics in order to have a quantifiable result.

San Francisco

Mann–Whitney U test

Metric	ρ-score	p-value
CDBN	11.106	$1.1715e^{-128}$
CNPR	124.379	0.0
NCBS	54.732	0.0
NCBN	1.273	0.202
CTBN	45.575	0.0

Our Null hypothesis establishes that both samples are totally different or unrelated.

Probability value (p-value) should be smaller than 0.05 (5%).

-The MW-U test is nonparametric statistical test which evaluates how probable is that a random selected value from one sample would have the same probability to be bigger or smaller than a random selected value from another sample.

-The MW-U test is equivalent to the T test for normal distributions.

- If we observe the results of the test, only one parameter is not totally unrelated.

- I chose an standard nonparametric test instead of comparing confidence intervals because according to the Mark Payton in its paper "*Overlapping confidence intervals or standard error intervals: What do they mean in terms of statistical significance?*" comparing intervals is less accurate than hypothesis tests. Another reason is that the p-value of a test tells how probable is that 2 random variables belong to the same population.

Statistical Test

Rome

Metric	ρ-score	p-value
CDBN	-68.646	$1.1715e^{-128}$
CNPR	57.471	0.0
NCBS	49.73	0.0
NCBN	-0.0752	0.94
CTBN	40.737	0.0

San Francisco

Metric	ρ-score	p-value
CDBN	11.106	$1.1715e^{-128}$
CNPR	124.379	0.0
NCBS	54.732	0.0
NCBN	1.273	0.202
CTBN	45.575	0.0

New York

Metric	ρ-score	p-value
CDBN	2.329	0.0198
CNPR	-0.182	0.854
NCBS	-0.259	0.795
NCBN	2.145	0.0319
CTBN	-4.61	$4.0116e^{-06}$

Orlando

Metric	ρ-score	p-value
CDBN	0.462	0.643
CNPR	0.87	0.383
NCBS	0.906	0.364
NCBN	1.587	0.112
CTBN	2.444	0.0145

Scenarios

Name	Area Km^2	Time Hours	Users
San Francisco	7145.486	575.425	536
Rome	10238.67	720	315
New York	618.699	22.658	39
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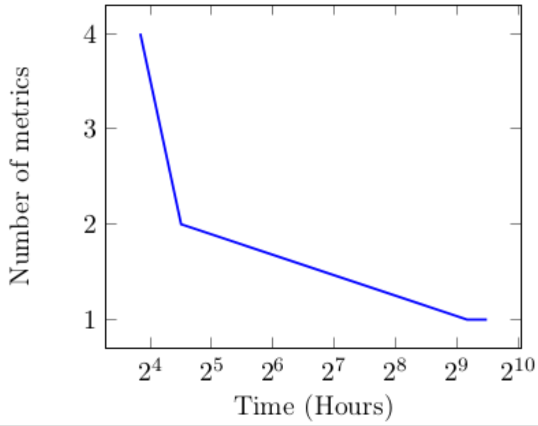
Relation Record time vs Number of similarities



- -If we look at the results of the tests of the 4 scenarios we can see that scenarios with a short record time can be better represented by TRAILS than scenarios with a long record time.
- -The reason of that is that mobile users change their behavior over time. For example, people have different routines in the day than in the night.
- -Other mobility models like CMM address this problem by changing the model periodically. Every 8 hours for example. On the other hand, we use the same TRAILS graph to represent a long trace.
- -In chapter 6 of my thesis in the section called Time invariability test we prove how metrics on traces change over time and how these changes affect our validation results.

Performance

Scenario	Processed traces	TRAILS graphs
San Francisco	474.2	357.5
Rome	755.3	559.8
New York	0.431	0.202
Orlando	1.3	0.576

< 43.37%

Size in Mega Bytes of mobility graphs

Scenario	Traces	TRAILS
San Francisco	82273.985	63318.721
Rome	35337.649	24466.268
New York	83.208	60.397
Orlando	56.683	40.563

< 28.1%

Time spent in seconds by simulating mobility graphs

-TRAILS graphs are in average 43.37% smaller than traces

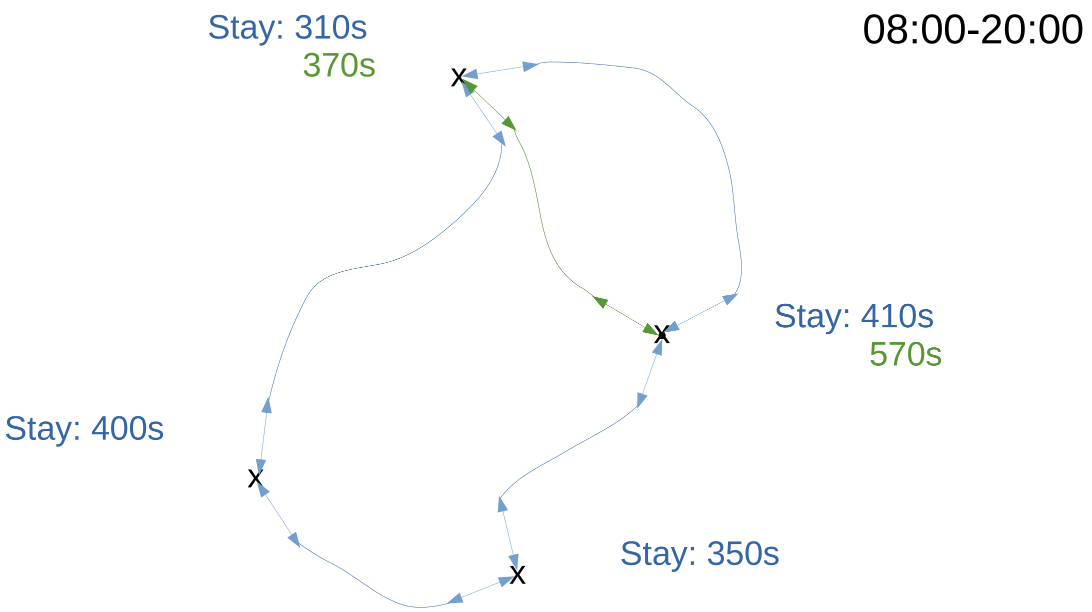
-and a TRAILS simulation requires 28.1% less time than traces in average

-The reason of it is that TRAILS replaces a lot of trace-points by a single POI and this action reduces the size of the graphs and the simulation time.

-To increase the similarities of TRAILS with long traces we propose to have different links and POIs available at different periods of time.

-For example if this is the complete TRAILS graph

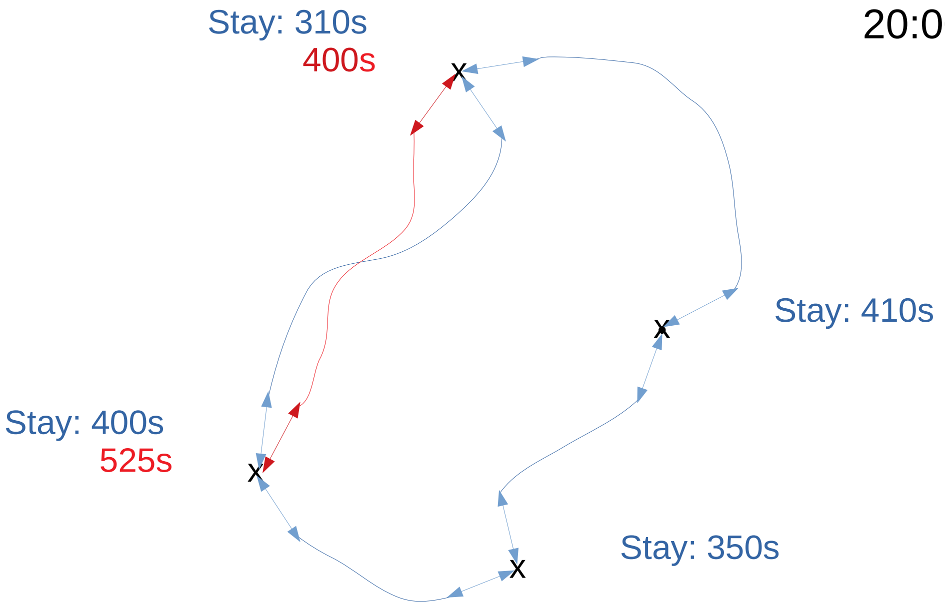
Recommendations



-This would be the graph for 8 am until 8 pm

Recommendations

20:00-08:00



-And this would be the graph from 8pm to 8am.

-By using this strategy we would be able to reduce the differences of the user's interactions between TRAILS and real scenarios.

Thank you!