Date:2022-01-09

Continue with the interim report and finish the **Results and discussion** section:

5. Results and discussion

This section demonstrates the results of some of the proposed algorithms in the previous section based on the piecewise linear EH model in (4).

5.1 Simulation Set up

The simulation set up follows system model given in section 5.1 as shown in Table 1, for the sake of not losing generality, the number of D2D and CUE are assumed to be the same for each generation of the system model.

TABLE 1: SIMULATION PARAMETER

Simulation parameter	Value
Radius of Cellular Network	250m
Number of D2D links N	**10~70**
Number of CUE links M	**10~70**
D2D communication distance	**10~70m**
Path loss exponent	3
EH power segment $[Pth_1\ Pth_2\ Pth_3\ Pth_4]$	[10 100 230.06 57368] uw
EH linear function coefficient $[k_1\ k_2\ k_3\ k_4]$	[0 0.3899 0.6967 0.1427]
EH linear function intercept $[b_1\ b_2\ b_3\ b_4]$	[0 -1.6613 -19.1737 108.2778]
Maximum harvested power $P_{max}^{harvested}$	250uw
Max transmission power P_{max}	23dBm
Circuit power consumption P_{cir}	20dBm
CUE transmission power P_k^C	23dBm
Initial Lagrange multipliers $\alpha, \beta, \gamma, \delta, \sigma$	0.1
Noise power N_0, N_1	-100dBm
Throughput requirement of D2D link i T_{min}^D	2bits/Hz
Throughput requirement of CUE k T_{min}^C	1bit/Hz

5.2 Pre-matching failure rate

As mentioned in the previous section, the pre-matching algorithm is used to separate all the SWIPT-Supported D2D links from the D2D sets. The Pre-matching failure rate (PMFR) will be the key factor to check if this algorithm works well which was defined as the ratio of the number of the Non-EH D2D links to the total number of D2D links. Two factors were taken into consideration to test how they will affect the pre-matching process: 1. The number of D2D links (or CUEs) 2. The communication distance.

As shown in Figure 6, the Pre-matching failure rate versus the number of D2D links has been plotted. As the number of D2D links increases, PMFR has decreased from 14% to around 12.7%. Since as the number of D2D user increases, for each D2D link j, it will have more CUEs trying to match with it which increases the possibility of having at least one CUE to be matched with it hence reduces the PFMR. Compared to the result of [4] in the specification section, the trend is basically the same while the peak of the PFMR in this project is a bit bigger when the number of D2D users is 10. The reason for that is because established minimum power segment Pth_1 for activating the piecewise linear EH model is different. It is an important factor for separating the SWIPT-Supported from the D2D set. As shown in Figure 7, pre-matching failure rate versus number of D2D links with different Pth_1 has been plotted. As shown in Figure 7, the trend for PFMR with different Pth_1 when increasing the number of D2D links is the same while the starting point is different. As Pth_1 increases, PMFR decreases, since Pth_1 is the minimum value of the power segment for activating the EH model, if it has been increased, it will increase the difficulty for each D2D link j to perform SWIPT hence increases PFMR.

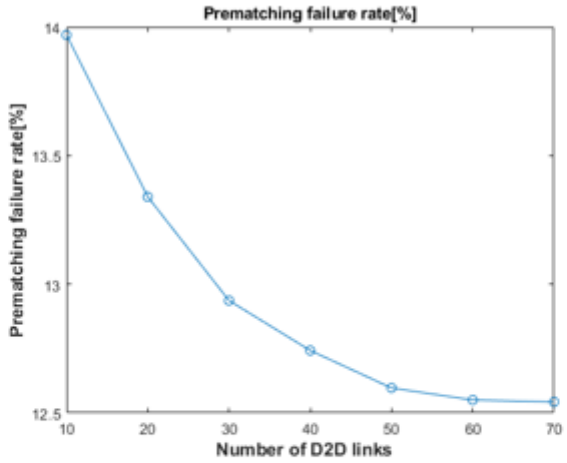

Figure 6: Pre-matching failure rate versus number of D2D links

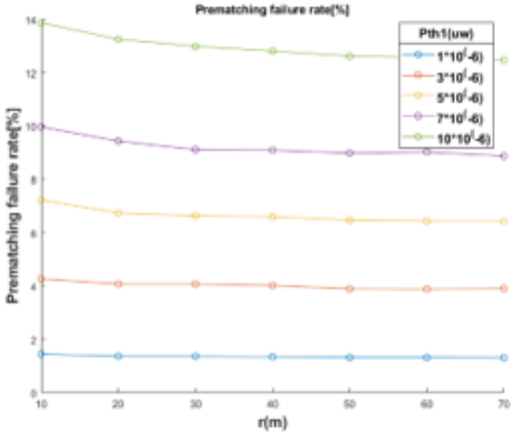

Figure 7: Pre-matching failure rate versus number of D2D links with different Pth1

As mentioned before, another factor which will affect PMFR is the communication distance. The communication distance is defined as the distance between D2D receiver and D2D transmitter, and each D2D transmitter will be paired with only one D2D receiver. The pre-matching failure rate versus the communication distance is plotted in Figure 8. PFRM increases from 8% to 100%, since when the communication distance was increased, the transmission power of each D2D transmitter needs to be increased to achieve the constraints of EH model to activate it and when the transmission power of the current D2D link i is greater than the maximum p transmission power P_{max}, it can not perform SWIPT hence increases PFMR. Compared to the result in [4] in specification section, the trend is the same while the ending point of the graph is different. Similarly, the reason behind it can be attributed to the minimum power segment Pth_1 for activating the EH model. To prove that, the pre-matching failure rate versus communication with different Pth_1 was plotted in Figure 9. Similarly, as Pth_1 increases, it will increase the difficulty for the current D2D link i to activate EH model hence fail to perform SWIPT.

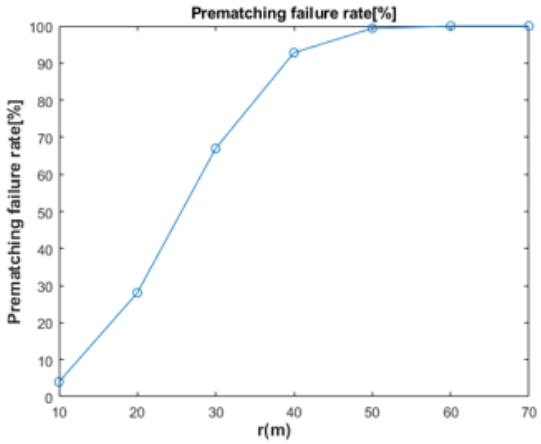

Figure 8: Pre-matching failure rate versus communication distance

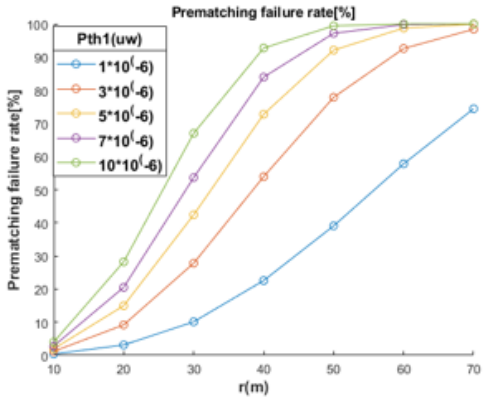

Figure 9: Pre-matching failure rate versus communication distance with different Pth1.

The reason why there are some new added results is because, the original result is a bit different although the trend is the same, and it has been proved that the Pre-matching failure rate can also be affected by the threshold power segment.

The **Milestone evaluation and future work** section was also finished:

6 Milestone evaluation and future work

So far, most of the work scheduled in the PID have been done following the scheduled date: A lot of literature review were done to help understand some of the unfamiliar technical concepts like D2D communication and Energy harvesting, and some reviewed work about using linear EH model to improve EE were listed to be compared with non-linear EH model. The basic D2D communication system has been generated shown in Figure 3 and 4. Most importantly, all the algorithms mentioned in [4] have been implemented and the pre-matching algorithm have been already simulated where the result is basically the same as that of [4].

Most of the work scheduled in PID is in process as expected while some of the finished work may have deviated from the original plan according to the schedule from PID. So, a new Gannt chart have been demonstrated in Figure 14 to show the modified date including the future work. As shown in Figure 14, two tasks have been highlighted which is two important milestones of this project, and the implementation part has been marked as a red star which means this milestone has achieved. Those highlighted with Yellow, and Blue are work needs to be done and work submitted respectively.

Figure 10: Modified Gannt Chart

Future work will mainly focus on simulating the rest of the implemented algorithms and further improving them, as shown in Figure 10, four added sub-tasks for all the simulation have been scheduled for 9 weeks. Since there are some parameters initialization issues from [4] which is relevant to the simulation of **outer loop algorithm**, some reviewed work related to that is also needed, that is the reason why the duration for simulation of **outer loop algorithm** is a bit longer.

6.1 Updated Risk Register

	Description of Risk	Risk Evaluation (L/M/H)	Chance of risk occurring (L/M/H)	Mitigation of Risk
1	Software Bugs (MATLAB)	M	L	Use some other software toolbox(NumPy, pandas and matplotlib from Python)
2	Ambiguity of code	M	H	Make clear comments when coding, and write clear documents
3	Long hour continuously working on the computer which can cause health problems to researchers.	M	L	Make good unit testing or make a message box when program finishes running. Manage time appropriately, always take health into consideration
4	Results loss or Data loss (USB keys)	H	L	Always upload your work to GitHub or google drive
5	Parameter initialization problem	H	M	More literature review and unit testing

6.2 Updated Back up plan(lockdown)

During lockdown, the main issues that can happen is that sometimes online literature review is not enough for some unfamiliar technical concepts or some mathematical tools where lack of universities' libraries can be serious issue. So, in this case, having a quick look at reference paper and making a list of some books that need to be borrowed in advance before lockdown can be a back up plan.

7. References:

[1] J. Lin, W. Yu, N. Zhang, Xin. Yang, H. Zhang and W. Zhao, "A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications", IEEE Internet of Things Journal., vol.4, no.5, pp. 1125 – 1142, March. 2017