49F Project Description: Resource Allocation in Satellite Integrated Cognitive Radio Networks

TABLE I
NETWORK PARAMETERS.

Parameter	Value	Explanation
$N_{f_{sat}}$	5	Total number of satellite bands
$N_{f_{ter}}$	10	Total number of terrestrial bands
λ_{PU}^{sat}	0.15 $\frac{user}{sec}$	Arrival rate of PUs at satellite link
λ_{PU}^{ter}	0.8 $\frac{user}{sec}$	Arrival rate of PUs at terrestrial link
λ_{SU}^{ter}	0.5 $\frac{user}{sec}$	Arrival rate of SUs at terrestrial link
λ_{HU}	0.3 $\frac{user}{sec}$	Arrival rate of HUs at the system
W_{sat}	36 MHz	Bandwidth of satellite link
W_{ter}	2 MHz	Bandwidth of terrestrial link
f_{sat}	20 GHz	Frequency of satellite link
f_{ter}	700 MHz	Frequency of terrestrial link

In this project you are going to propose a resource allocation strategy for satellite and terrestrial coexisting cognitive radio network system. You will investigate the network throughput.

Our users can request videos of high quality. Each user makes a request for some video(content). Each content consists of one base chunk (for standard quality) and one enhancement chunk (for high quality). Note that without base chunk, no viewing of a content is possible. You can assume that a requested content chunk is available both in the satellite and in the BS but not in the local cache. You will propose a decision mechanism whether you will get the content from the satellite or from the BS. Our user devices are very clever. They are the real user of the satellite link and they can also access the terrestrial link opportunistically(until the real owner of the band comes). They are named as hybrid users (HUs). They are **only licensed user (primary user (PU)) at the satellite link** and **only secondary user (SU) at the terrestrial link**. If an HU gets a content from the satellite the service cannot be terminated by other users. However, the activity of HUs can be terminated and forced to move to other frequencies at the terrestrial link due to the appearance of licensed users. Satellite link seems to be more preferable since our users are PU in this link but the satellite link is poor in terms of throughput (bps). So, there is a trade off. You are going to propose resource allocation method. You will calculate the throughput of HUs. You don't need to solve analytically. The simulation is sufficient. Some parameters for the simulation are given in Table I.

I. NETWORK MODEL

Our network is given in Figure 1. There are two network segments. These segments are the satellite link and the terrestrial link. The satellite link is at 20 GHz range consisting of 5 bands each having 36 MHz bandwidth. There are baseline PUs with mean arrival rate λ_{PU}^{sat} where the arrival is a Poisson process. The terrestrial link is at 700 MHz range consisting of

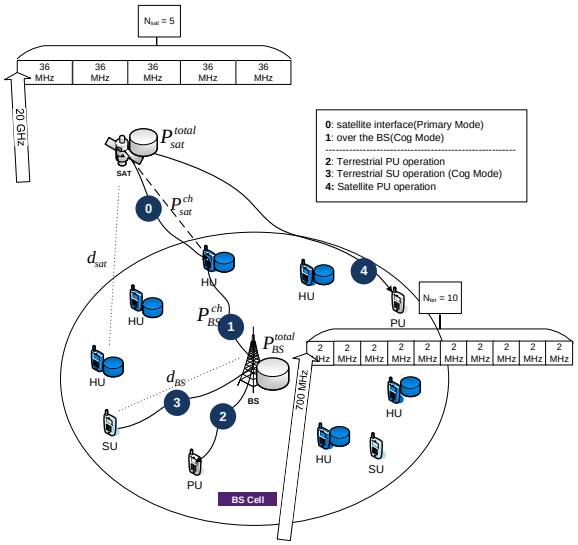

Fig. 1. System model.

10 bands each having 2 MHz bandwidth. There are baseline PUs with mean arrival rate λ_{PU}^{ter} where the arrival is a Poisson process. There are also baseline SUs with mean arrival rate λ_{SU}^{ter} where λ_{SU}^{ter} is the parameter for the Poisson process. There are our hybrid users (HUs) with mean arrival rate λ_{HU}. They can use either the satellite link or the terrestrial link.

TABLE II
RECEIVED POWER STRENGTH PARAMETERS.

Parameter	Value	Explanation
f_{sat}	20 GHz	Frequency of satellite link
f_{ter}	700 MHz	Frequency of terrestrial link
G_{sat}	$2.5 \cdot 10^4$	Gain of the satellite
G_{BS}	$4 \cdot 10^{-5}$	Gain of the base station
$G_{dev(HU)}$	$6 \cdot 10^{-2}$	Gain of a hybrid user
$G_{dev(PU_{ter})}$	$11 \cdot 10^{-2}$	Gain of a primary user requesting service at terrestrial link
R_{BS}	300 m	The radius of the BS
d_{sat}(LEO)	300 km	Distance from satellite to earth
d_{BS}	150 meter	The distance between any user (PU,SU,HU) and the BS
P_{sat}^{total}	240 W	Total transmission power of the satellite
P_{BS}^{total}	60 W	Total transmission power of the BS
P_{sat}^{ch}	$\frac{P_{sat}^{total}}{N_{f_{sat}}}$	Per channel transmission power of the satellite
P_{BS}^{ch}	$\frac{P_{BS}^{total}}{N_{f_{ter}}}$	Per channel transmission power of the BS

For the calculation of service duration you can use free space path loss model. By using this model, you can calculate the received power strength of PUs that get service from the

satellite over the satellite link. Similarly, the received power strength of PUs that get service from the BS over the terrestrial link, the received power strength of SUs that get service from the BS over the terrestrial link are calculated. For our HUs that retrieve content chunk from the satellite over the satellite link and HUs that retrieve content chunk from the BS over the terrestrial link, the received power strengths are calculated seperately. The necessary parameter set is given in Table II. The power strength calculation for all types of users in free space path loss model is given as follows:

$$P^{rec}_{PU_{sat}} := \frac{P^{ch}_{sat} \times G_{sat} \times G^{D}_{r} \times c^2}{(4\pi \times f_{sat} \times d_{sat})^2} \tag{1}$$

$$P^{rec}_{PU_{ter}} := \frac{P^{ch}_{BS} \times G_{BS} \times G_{dev(PU_{ter})} \times c^2}{(4\pi \times f_{ter} \times d_{BS})^2} \tag{2}$$

$$P^{rec}_{SU_{ter}} := \frac{P^{ch}_{BS} \times G_{BS} \times G^{D}_{r} \times c^2}{(4\pi \times f_{ter} \times d_{BS})^2} \tag{3}$$

$$P^{rec(sat)}_{HU} := \frac{P^{ch}_{sat} \times G_{sat} \times G_{dev(HU)} \times c^2}{(4\pi \times f_{sat} \times d_{sat})^2} \tag{4}$$

$$P^{rec(BS)}_{HU} := \frac{P^{ch}_{BS} \times G_{BS} \times G_{dev(HU)} \times c^2}{(4\pi \times f_{ter} \times d_{BS})^2} \tag{5}$$

TABLE III
CAPACITY PARAMETERS.

Parameter	Value	Explanation
W_{sat}	36 MHz	Bandwidth of satellite link
W_{ter}	2 MHz	Bandwidth of terrestrial link
N^{sat}_0	$10^{-18}\frac{Watt}{Hz}$	Noise at satellite link
N^{ter}_0	$1.5 \cdot 10^{-19}\frac{Watt}{Hz}$	Noise at terrestrial link

Then, with the Shannon's capacity formula under Additive White Gaussian Noise (AWGN), you can retrieve the corresponding channel capacities. The necessary parameter set is given in Table III. Capacity calculations for all user types with Shannon's formula are given as follows:

$$C^{x}_{PU} := W_x log_2(1 + (\frac{P^{rec}_{PU_x}}{N^{x}_0 \times W_x})) \text{ where } x \in \{sat, ter\} \tag{6}$$

$$C^{ter}_{SU} := W_{ter} \times log_2(1 + (\frac{P^{rec}_{SU_{ter}}}{N^{ter}_0 \times W_{ter}})) \tag{7}$$

$$C^{sat}_{HU} := W_{sat} \times log_2(1 + (\frac{P^{rec(sat)}_{HU}}{N^{sat}_0 \times W_{sat}})) \tag{8}$$

$$C^{BS}_{HU} := W_{ter} \times log_2(1 + (\frac{P^{rec(BS)}_{HU}}{N^{ter}_0 \times W_{ter}})) \tag{9}$$

Our network consists of 100 distinct contents. Each content consist of two chunks, one base and one enhancement. The content chunk sizes are exponentially distributed. We assume that PUs and SUs request standard quality contents (videos) while HUs request high quality contents (videos). i.e. PUs and SUs request only base chunks while HUs request both base and enhancement chunks. The mean content chunk sizes are given in Table IV. Without the base chunk, enhancement chunk is of no use. Therefore, First you should request the base chunk. If you retrieve it properly, then you should request the enhancement chunk. Content model is depicted in Figure 2.

TABLE IV
CONTENT PARAMETERS.

Parameter	Value	Explanation
$s(\hat{HU}, v_b)$	25 Mbits	Mean base content chunk size requested by an HU
$s(\hat{HU}, v_e)$	5 Mbits	Mean enhancement content chunk size requested by an HU
$s(\hat{PU^s}, v_b)$	25 Mbits	Mean base content size requested by a PU at satellite link
$s(\hat{PU^t}, v_b)$	25 Mbits	Mean base content size requested by a PU at terrestrial link
$s(\hat{SU}, v_b)$	25 Mbits	Mean base content size requested by a SU at terrestrial link
r_{enh}	1	The ratio of HUs that request both base and enhancement content chunks (ratio of high quality consumers)

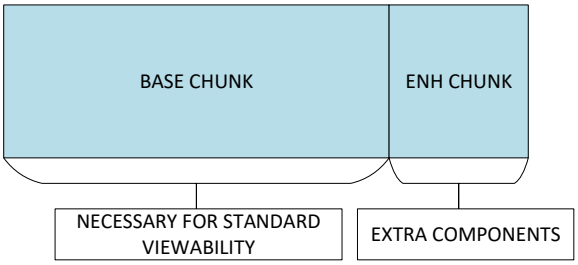

Fig. 2. Content model.

Dividing the size of the content chunk by the channel capacity, the corresponding service durations are calculated as follows:

$$\Delta^{x}_{PU} := \frac{size^{x}_{PU}}{C^{x}_{PU}} \text{ where } x \in \{sat, ter\} \tag{10}$$

$$\Delta^{ter}_{SU} := \frac{size^{ter}_{SU}}{C^{ter}_{SU}} \tag{11}$$

$$\Delta^{x}_{HU} := \frac{size_{HU}}{C^{x}_{HU}} \text{ where } x \in \{sat, BS\} \tag{12}$$

We assume that the requested content chunk is available both in the satellite and the BS but not in the local cache. You will write a decision algorithm for the selection of network segment(content chunk will be fetched over the satellite link or the terrestrial link). You can ask these questions: Does there exist idle satellite bands currently? What about terrestrial links? Other than availability of bands what can be used for the selection? Note that the base chunk of some content is more important than the enhancement chunk of the same content. Therefore you will propose different algorithms for different chunk types. For both the base chunks and enhancement chunks, you need to explain explicitly your proposed method for the selection among the satellite or the BS seperately and justify.

After the selection of the network segment (resource allocation), the PUs and HUs in PU mode, once they start their content chunk fetching they will continue until the content

chunk is retrieved. However, SUs and HUs in SU mode even if they start their operations they can be preempted by PUs. As the PUs are the real owners of the channels and SUs are renters, PUs have higher priority over SUs. If a PU starts to use a band that is currently used by some baseline SU/HU in SU mode in the terrestrial link that baseline SU/HU in SU mode preempts that band. If there exists some idle terrestrial band it can continue its operation. If no idle terrestrial band exists, it is dropped. Note that there will be another priority differentiation between base and enhancement chunks. Base chunks have higher priority over enhancement chunks. Therefore, if a base chunk cannot find an idle band neither in the satellite link nor in the terrestrial link(an opportunity for the resource allocation), it can remove a band that currently transmits some enhancement chunk. That enhancement chunk is forcibly dropped.

II. Content and Caching Model

There are 100 distinct contents in our network. Each content has one base and one enhancement chunk. PUs and SUs request only base chunks while HUs request both of the chunks. For each content you will assign a probability of being requested. You can use zipf distribution for the assignment of content request probabilities. Zipf distribution is used for popularity modelling. More popular contents will have a higher probability of being requested. You can take zipf distribution parameter s equal to one.

You do not need to model the satellite, the BS or HU device caches. You can assume that a requested content is not available in the local cache but both in the satellite and in the BS.

III. Performance Metrics

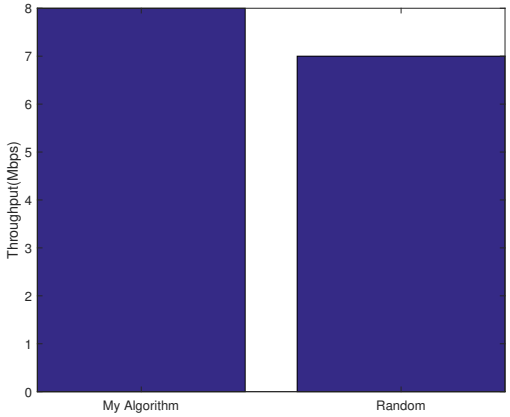

Fig. 3. Result Format.

You need to calculate the overall throughput of HUs. That is you will run the simulation and sum up the fully transmitted base chunk sizes that are requested by HUs and the size of the portion of successfully transmitted enhancement chunks that are requested by HUs and divide over the simulation time.

You will run your proposed algorithms for base and enhancement chunks together and calculate a throughput value. Then you will run random satellite and BS selection algorithm both for base and enhancement chunks and calculate a throughput value. These two results will be given in the format as in Figure 3.

IV. Submission

You can use either Matlab or phyton as development environment. You will make a demo of your simulation and submit a report. Note that you should write down the assumptions that you have done. Also justify your proposal for resource allocation both for base and enhancement chunks.