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Agenda Item: **Ad hoc 14**

Source: **Philips**

Title: **Performance of CPCH**

Document for: **Discussion**

Summary

This document presents analytical results for performance of CPCH. Various alternatives are compared in terms of number of access attempts and average delay.

1. Background

The current proposal for CPCH [1,2,3] is illustrated in Figure 1. It includes an initial access phase with power ramping of RACH-like preamble signatures and acknowledgement via an AICH (Acquisition Indicator Channel). A maximum of one access attempt per access slot is given a positive acknowledgement. The initial access is followed by a contention resolution phase where the UE randomly selects from another set of preamble signatures with a different scrambling code. The network would normally respond (on an AICH-like channel) to the transmission received with greatest power, thus granting permission to send the packet. The acknowledgements for the contention and resolution phases can be distinguished by different channelisation codes. Thus if more than one UE selected the same initial preamble, the probability of selecting the same signatures in the contention resolution phase is reduced in proportion to the number of available signatures.

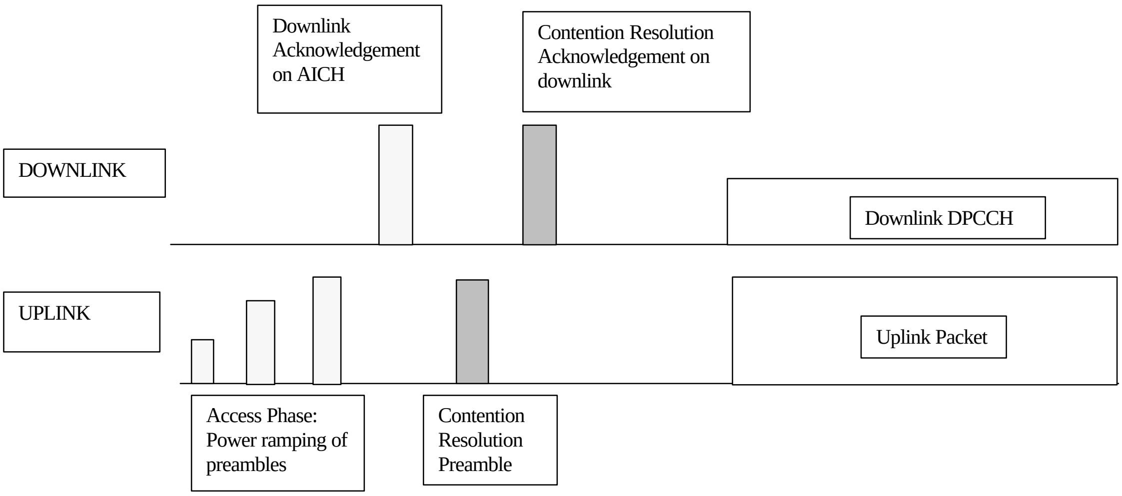

Figure 1: Basic CPCH scheme

In order to reduce the probability of a UE requesting a CPCH which is not available it has been proposed that the CPCH status (i.e. which channels are free) can be obtained by monitoring activity on the AICH. There may be other methods to achieve this, such as broadcasting status information (e.g. as proposed in [6]). It has also been proposed that performance can be improved by allocation of the CPCH at the end of the contention resolution phase [e.g. in 4]. A combination of these ideas is described in [5].

Simulation of these alternatives could be used to compare performance. However, analytical methods can be much less time consuming, provided the problem can be made tractable. Here we make some simplifying assumptions and obtain useful insight into the behaviour of various implementation options for CPCH.

In order to compare performance of various options, we must make some common assumptions about the deployment. As a starting point these are:

- 16 signature sequences available for both access and collision resolution phases
- 16 CPCH channels with equal bit rates (say 60kbps)
- All “RACH sub-channels” are available for CPCH
- The average packet length 30ms (three frames).

2. Analytical Approach to Calculation of Throughput

2.1 Current CPCH

The Current CPCH transmission is modelled as shown in Figure 2

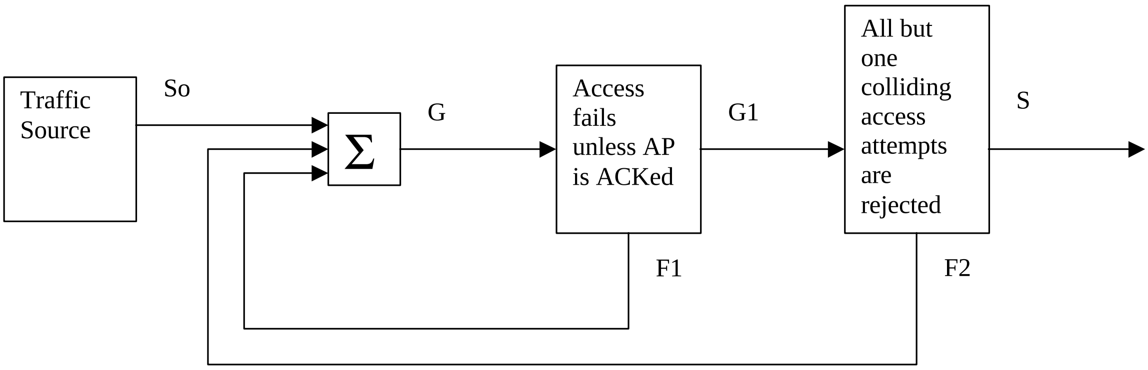

Figure 2: Model of Current CPCH

Key Assumptions

- Offered traffic (So) has Poisson statistics
- Access attempts (G) have (approximately) Poisson statistics
- Collision resolution is perfect (ideal algorithm in which one colliding access is accepted and the others are rejected)
- Failure probability of CPCH protocol is neglected (i.e. all preambles and corresponding ackowledgements are received without errors)
- Failure of packet transmission (e.g. due to CRC failure) is not considered
- Constant offered traffic rate
- All the offered traffic is transmitted (i.e. So = S), so no limit on re-transmissions

The traffic source generates packets with an average rate So. Each packet results in a CPCH access attempt (i.e. AP = access preamble transmission). These accesses, together with re-tries from previous failed attempts give the total access rate G. Some of these attempts will fail because there is no resource available. Others will fail because only one CPCH can be allocated at a time. Rejection at this stage would normally indicated by a NACK, but in any case would be assumed by the UE if it did not receive an ACK. In the event of a NACK, some random back-off could be applied before another access attempt is made. If the failure rate after the access phase is F1, and the rate of remaining attempts is G1, then G = G1+F1. If one signature is acknowledged in the access phase, more than one UE may have sent that signature. Such collisions should be resolved in the collision resolution phase (which we assume for the moment to be perfect), giving a successful access rate S = G1-F2. We also see that G = So+F1+F2.

If all packets are eventually sent, then the traffic throughput S will be the same as the offered traffic So. However, there will be a load dependent delay.

It is possible to analyse this model do in a straightforward way if the offered traffic, (So), and the access rate, G, can both represented (at least approximately) by Poisson arrival processes. This is certainly a reasonable assumption for So, but is only a good approximation if the failure rates F1 and F2 are low, or if the resulting re-tries are sufficiently randomised. However, in practice it would be easy, and probably beneficial, to incorporate a small random back-off interval such that this “Poisson assumption” is reasonable.

We define the number of signatures available for access preambles as Nsig and a number of CPCH channels as Nc. It is convenient, but not essential, if Nsig=Nc. For the moment we consider the case where all CPCH channels are assigned the same bit rate.

We now make use of the following:
Probability of k arrivals in time interval T, with average arrival rate S per unit time. For convenience we assume T=1 (i.e. duration of an access slot).

Equation 1

$$P_{arrive}(S,k) = \frac{(ST)^k e^{-ST}}{k!}$$

Probability that N of the CPCH channels are free out of a total of N_c, with traffic rate S and average packet duration L. Note that the fraction of CPCH channels which are occupied is SL/N_c.

Equation 2:

$$P_{free}(S,N) = \frac{N_c!}{N!(N_c - N)!}\left(\frac{SL}{N_c}\right)^{N_c - N}\left(1 - \frac{SL}{N_c}\right)^{N}$$

Probability that a specific AP signature is received, and the corresponding CPCH channel is available, with access rate G and traffic throughput S. Here we assume that the UE’s do not determine the availability of CPCH channels in advance (e.g by monitoring AICH transmissions). Also note that the access attempts are divided equally between the available N_{sig} signatures.

Equation 3

$$P_{rec}(G,S) = \left(1 - P_{arrive}(G/N_{sig},0)\right)\left(1 - \frac{SL}{N_c}\right)$$

Knowing that a successful access will result as long as one AP signature is received and the corresponding CPCH channel is available, we can now write the traffic throughput as:

Equation 4 $$S_{CPCH}(G) = 1 - \left(1 - P_{rec}(G,S)\right)^{N_{sig}}$$

This relation can be solved numerically for a given value of G after setting S_{CPCH}=S.

Now we find the number of access attempts which are rejected during collision resolution. Considering a single signature we know that only one arrival would be accepted and the other arrivals rejected as collisions. We also know the average number of arrivals on a signature which has one or more arrivals. Therefore the average number of access attempts rejected from the signature which is acknowledged in the access phase is given by:

Equation 5 $$C_{rej}(G) = \frac{G/N_{sig}}{1 - P_{arrive}(G/N_{sig},0)} - 1$$

Since this is the average number of rejected attempts (due to collision) per successful attempt, we can write the rate of failures due to collisions as F2 = S.C_{rej}(G). The rate of initial access failure, due to blocking of CPCH channels, and limitation of only one channel assignment per time slot is F1 = G-S-F2.

2.2 CPCH with Code Allocation

The above analysis can be extended to consider the case where the CPCH channel is assigned at the end of the collision resolution phase as proposed in [4]. The same basic model is used as shown in Figure 1.

We now need the probability that any AP signature is received given that at least one CPCH channel is available. Again we assume that the UE's do not determine the availability of CPCH channels in advance (e.g. no monitoring of AICH transmissions).

Equation 6 $$P_{rec-CA}(G,S) = \left(1 - P_{arrive}(G,0)\right)\left(1 - \left(\frac{SL}{N_c}\right)^{N_c}\right)$$

We can now write the traffic throughput as:

Equation 7 $$S_{CPCH-CA}(G) = 1 - \left(1 - P_{rec-CA}(G,S)\right)^{N_{sig}}$$

This can be solved numerically to give the traffic rate as a function of the access rate.

The number of access arrivals rejected due to collision on one signature is given by Equation 5 so, in a similar way to the case of CPCH with no monitoring, the rate of failures due to collisions is given by F2=S.C_{rej}(G) and the initial access failure rate is F1=G-S-F2.

2.3 CPCH with Status Monitoring

We now assume some means of perfect monitoring of CPCH status is implemented. This means that UE will only attempt to access a CPCH channel when it is available, and that all attempts will fail if no channels are free. The model must therefore be altered slightly as in Figure 3.

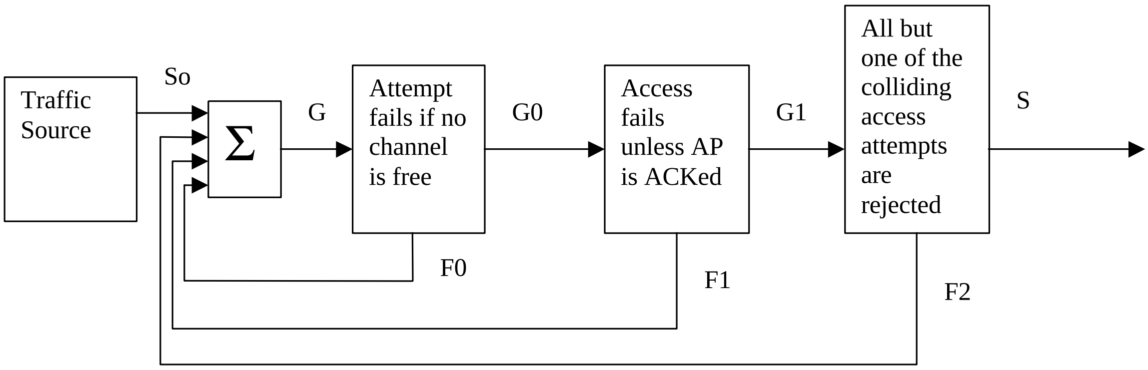

Figure 3: CPCH model with status monitoring

Thus we can see that F0=G.P_{free} (S,0), where the access rate for new traffic and re-tries is G, but the access rate appearing on the radio channel is G-F0. Since there will be a successful access in any slot where there is at least one access attempt, provided there is a free CPCH channel, we can write the traffic rate as:

Equation 8

$$S_{CPCH-M}(G,S) = \left(1-P_{arrive}(G,0)\right)\left(1-\frac{SL}{N_c}\right)^{N_c}$$

This can be solved numerically to give the traffic rate as a function of the access rate G. This result assumes that the CPCH's which are free according to the monitored CPCH status are still free when the access preamble is sent.

The average number of arrivals rejected from one signature due to collision can be derived by modification of Equation 5 This is necessary to allow for fact that the collision probability increases as the number of free channels is reduced, since the number of available signatures is also reduced.

Equation 9

$$C_{rej-M}(G) = \frac{\sum_{N=1}^{N_c}\left(P_{free}(G,N)\left(\frac{\frac{G.N_c}{N.N_{sig}}}{1-P_{arrive}\left(\frac{G.N_c}{N.N_{sig}},0\right)}-1\right)\right)}{\sum_{N=1}^{N_c}P_{free}(G,N)}$$

The rate of failures due to collisions is given by F2=S.C_{rej-M}(G) and the initial access failure rate is F1=G-F0-S-F2.

2.4 CPCH with Status Monitoring and Code Allocation

If we consider the CPCH enhancements proposed in [5], then the model in Figure 3 is also applicable. Similarly, the failure rate due to channel blocking is given by F0=G.P_{free}(S,0), and the traffic rate is given by Equation 8. However, the fraction of access attempts rejected due to collision is now given by Equation 5 since all the signatures can be used. Again, the access rate appearing on the radio channel is G-F0.

2.5 RACH/FACH/DCH

It is also possible to consider a similar approach in using the RACH/FACH to set up a DCH for packet transmission. Assuming a given limited number of DCH's are available (e.g. 16), then a DCH can always be allocated by the RACH/FACH up to this limit.

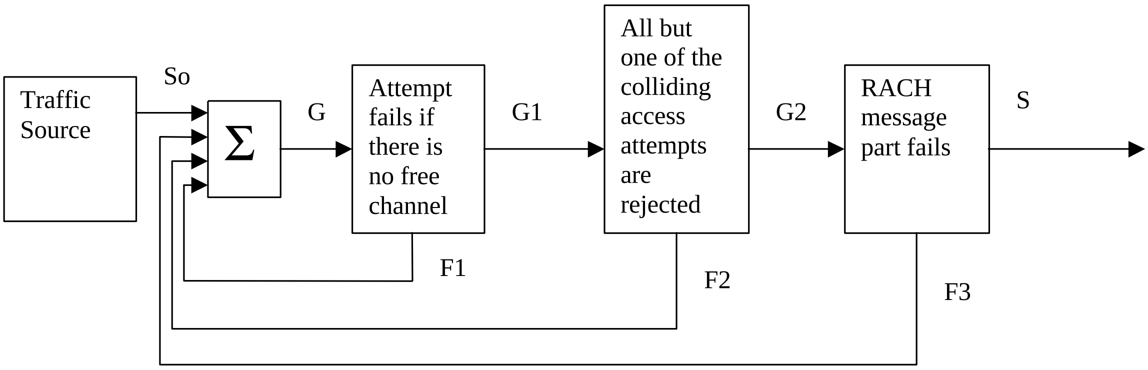

Figure 4: RACH/FACH/DCH model

The traffic rate can be estimated by assuming that a DCH can be allocated whenever a request is received using one of the available signatures, provided a DCH is free. The total is then the sum of the traffic arising from each signature. This effective traffic rate is reduced by the probability, P_{mfail}, that the RACH message part is not correctly received.

Equation 10 $$S_{RACH}(G,S) = (1-P_{mfail})N_{sig}\left(1-P_{arrive}(G/N_{sig},0)\right)\left(1-\frac{SL}{N_c}\right)$$

Again, this can be solved numerically to give the traffic rate as a function of the access rate. The number of access attempts rejected due to collision is given by Equation 5. The failure probability of the RACH message part is mainly determined by the deployment scenario. Here we assume a value of 0.05. Thus F2 = $S.C_{rej\text{-}RACH}(G,S)$, and with F3 = $S.P_{mfail}$, we can derive F1 = G-S-F2-F3

2.6 Access Rate Results

The above analysis enables us to give results for throughput and access rate for packet transmission in the following cases

1. Current CPCH with no monitoring of status
2. Current CPCH with ideal monitoring of CPCH status
3. Possible CPCH with code allocation and no monitoring of CPCH status
4. Proposed CPCH in [5] with code allocation and ideal CPCH status monitoring
5. RACH/FACH/DCH

Results are shown in Figure 5 with 16 access signatures and 16 CPCH’s (or 16 DCH’s in the case of RACH/FACH/DCH). The average packet length (L) is30ms. This allows for 10ms of overhead due to power control preamble, and a 20ms duration for the packet data. This probably represents a worst case in terms of access attempts and the CPCH channel assignment rate.

Here it is convenient to normalise to the maximum possible throughput (N_c/L). This is the packet rate which would be achieved if all the CPCH channels were permanently occupied with data packets..

The access attempts shown include only those appearing on the radio channel. This corresponds to the quantities G for CPCH with no monitoring, CPC with code allocation and RACH/FACH/CDCH, and G-F0 for CPCH with monitoring and the proposed CPCH.

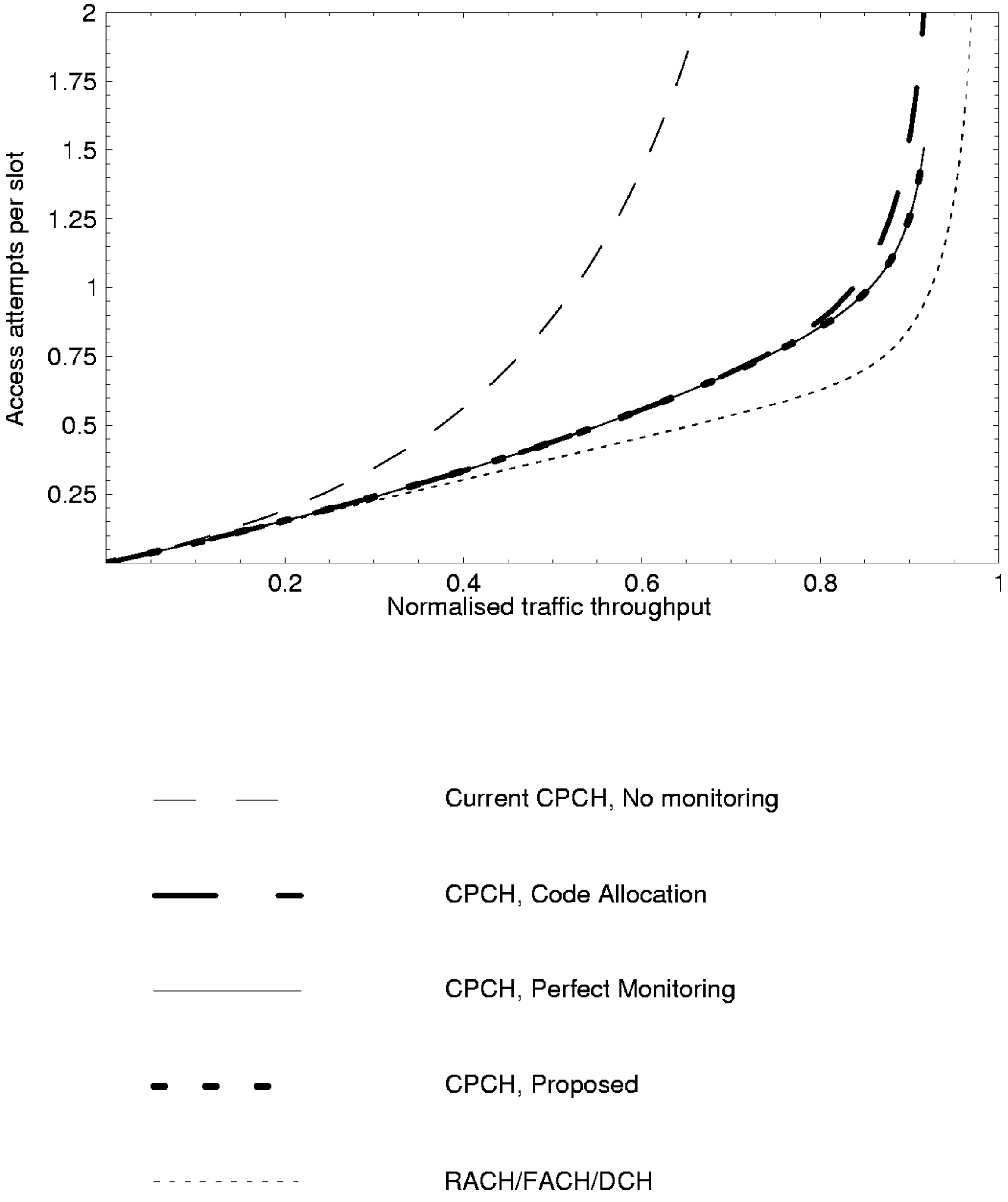

Figure 5: Access rate per access slot vs normalised throughput for various packet transmission schemes (16 signatures, 16 Channels, 30ms packet duration)

In Figure 5 we can see that with the current CPCH without monitoring the access rate increases rapidly with the throughput. Here, many access attempts fail because the CPCH associated with the selected signature is already in use. This leads to a high proportion of accesses due to re-tries. In all the other cases the access rate begins to increase rapidly beyond about 0.8 of the maximum throughput.

The assumptions used here require that the throughput is equal to the offered traffic. In practice, if there were a limit to the number of re-tries, some of the offered traffic would be rejected, and this condition would not hold.

The performance of code allocation alone is slightly worse than that achieved with perfect monitoring or the proposed CPCH (which has both code allocation and monitoring).

It is interesting to note that RACH achieves slightly better results than any of the CPCH schemes, apparently because it does not suffer from the limit of one channel allocation per access slot.

The average number of access attempts per slot would typically be less than one for reasonable loading levels. This seems intuitively reasonable given that CPCH can (currently) only allocate one channel per slot. If the packet length were shorter than 30ms, or the number of channels greater than 16, it might be necessary to support more than one allocation per access slot. However, for short packets the RACH might be preferable to CPCH.

An ideal scheme could in principle achieve 100% loading with an average of 0.71 access attempts per slot, and the best proposals considered here are not far from that ideal.

It is also of interest to consider the performance for other configurations. In Figure 6 results are given for a system with 4 signatures used to allocate 4 channels. The general shape of the curves is very similar to those in Figure 5, except that the access rate is lower (by a factor 4). One notable difference is that CPCH with monitoring now shows a more significant advantage over CPCH with code allocation. The reason appears to that with such small number of channels, many of the access failures are due to lack of any available channel. The CPCH schemes with monitoring avoid attempting to access when there is no free channel, while a scheme with code allocation alone will continue to transmit access preambles, even when all the channels are blocked.

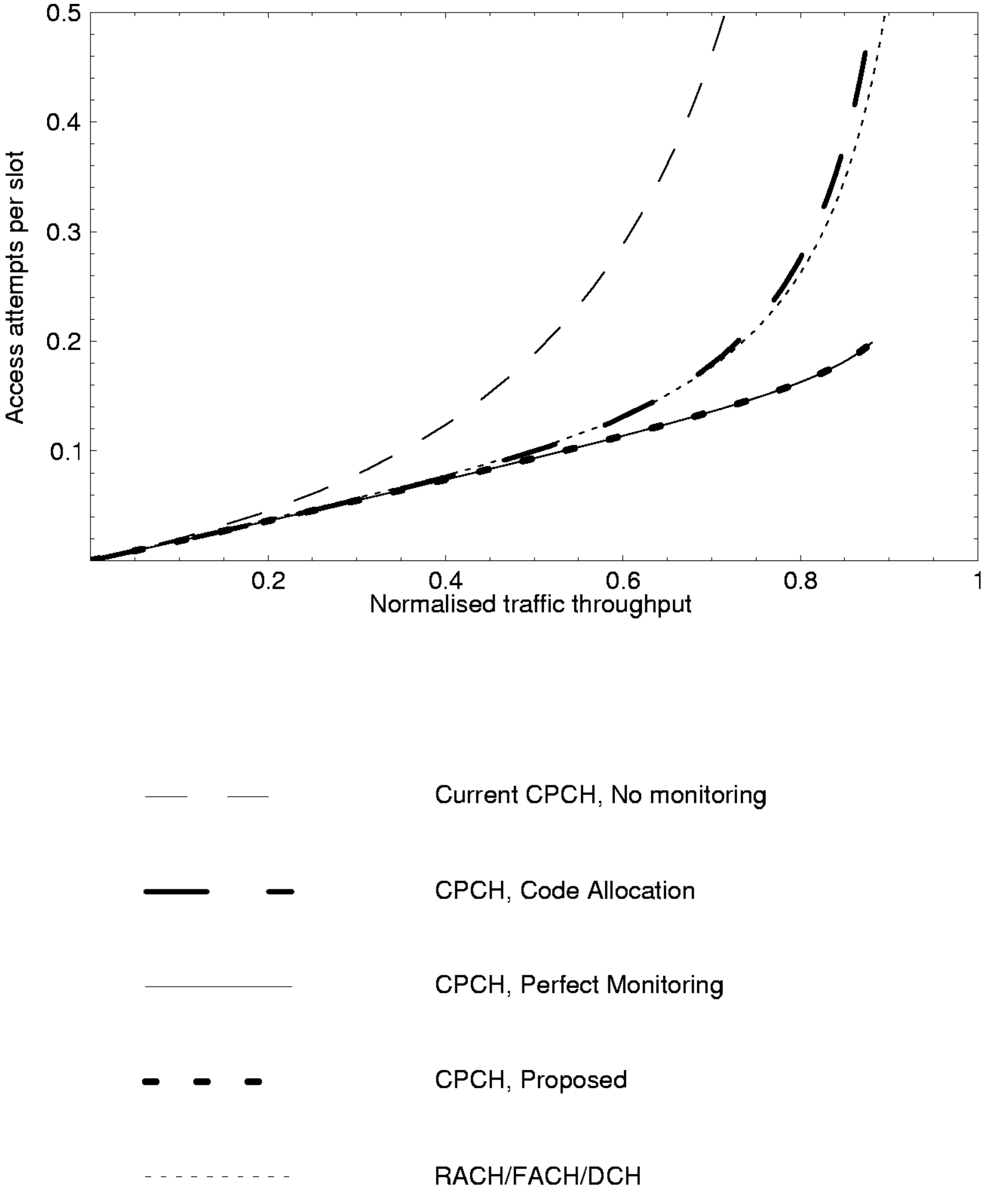

Figure 6: Access rate per access slot vs normalised throughput for various packet transmission schemes (4 signatures, 4 channels, 30ms packet duration)

2.7 Collision Results

The rate of access failures due to collisions is shown in Figure 7. A collision arises when more than one UE receives an acknowledgement in the access phase. Here the model assumes that the collision resolution procedure is perfect (i.e. when a collision is present one access attempt is accepted and all the others are rejected), or if not perfect, that the rate of unresolved collisions is small enough to neglect. While this assumption will not strictly accurate in a practical system it does allow the effect of various parameters on collision rate to be investigated.

In Figure 7 we can see that the collision rejection rate is generally low (typically less one access attempt every 20 slots), but for the current CPCH (with or without monitoring) rapidly increases with load. Without monitoring, this increase arises because of the large number of access attempts needed to find a free channel. It is initially a little surprising that the collision failure rate is slightly higher with monitoring, than without, but this occurs because as the throughput increases, more CPCH channels become occupied, which means that the remaining accesses are confined to a reducing number of signatures.

The other cases, CPCH with code allocation, the proposed CPCH and RACH/FACH/DCH all show low collision failure rates, increasing as the throughput reaches 0.8.

In the CPCH proposals considered here, with 16 signatures for collision resolution, the collision resolution mechanism should be capable of dealing correctly with about 93% of all collision events. Thus at high loading, with a collision rate of around 0.05 per slot, one collision would be unresolved about every 320 access slots (42 frames). For a packet rate of 4 per frame (about 0.8 of the theoretical maximum capacity), this suggested collision rate of 0.05 would correspond to one corrupted packet in about 170, less than 1% of the total throughput.

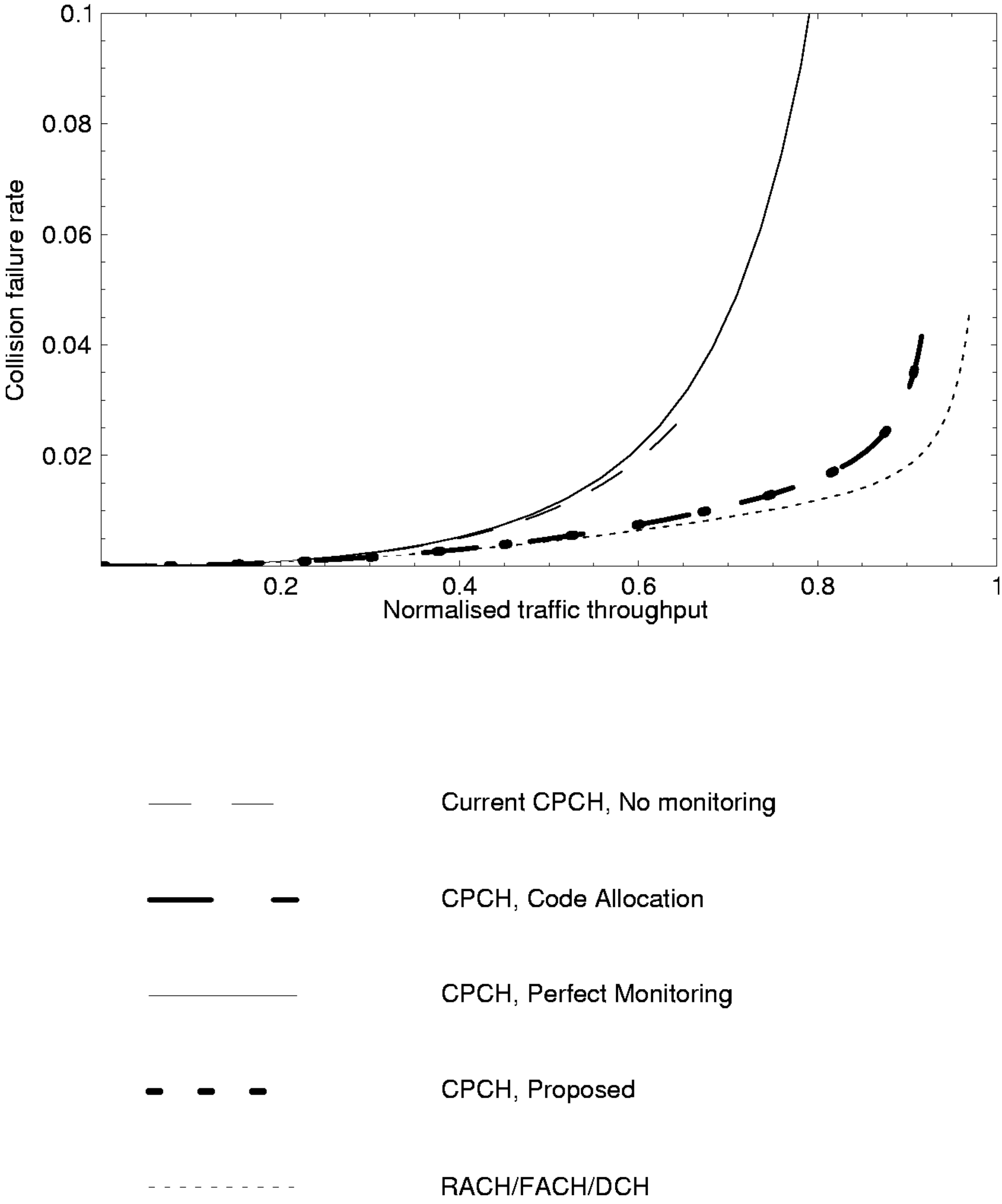

Figure 7: Collision failure rate per access slot vs Normalised throughput (16 signatures, 16 channels, 30ms packet duration)

3. Analysis of Packet Delay

3.1 Current CPCH without status monitoring

We propose the structure shown in Figure 8 as a basis for estimation of packet transmission delay. Considering a number of access attempts in a slot, G, of these, S will succeed, F1 will fail due lack of free channels and the limitation of one CPCH allocation and F2 will fail due to collision.

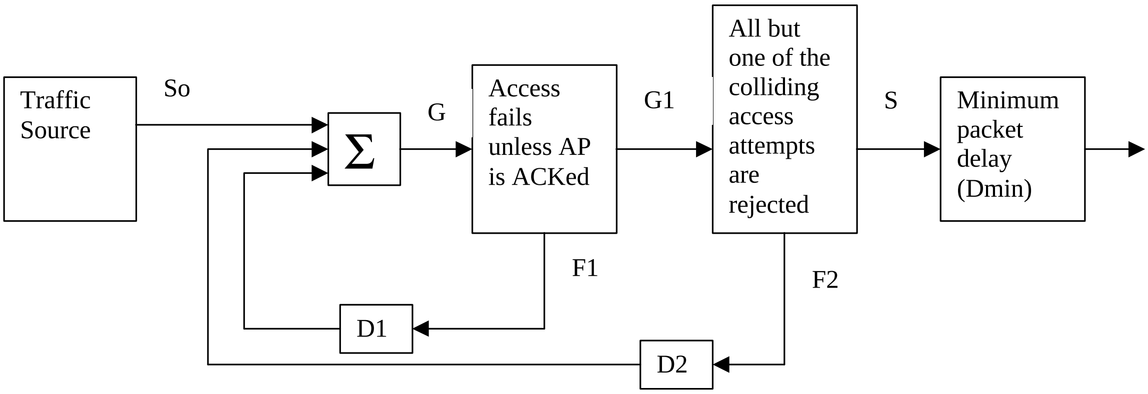

Figure 8: Model for CPCH delay calculation

The successful access attempts will lead to packet transmission with some minimum delay D_{min} (actually an average minimum delay). The failures F1 and F2 will incur delays D1 and D2 respectively, before being returned as repeated access attempts. The average delay up to this point is $(S.D_{min}+F1.D1+F2.D2)/G$. Considering only the re-tries, the same proportions will succeed and fail, but on average these will also incur the same additional delay. Considering the average delay resulting from successive re-tries we can write the following:

Equation 11

$$\begin{aligned} D_{av} &= \frac{(S.D_{\min} + F1.D1 + F2.D2)}{G}\left(1+\sum_{i=1}^{\infty}\left(\frac{G-S}{G}\right)^{i}\right) \\ &= D_{\min} + \frac{(F1.D1 + F2.D2)}{S} \end{aligned}$$

Note that for low failure rates (i.e. small values of F1 and F2), the throughput S is approximately equal to G and the average delay approaches Dmin.
Average values for Dmin and D1 and D2 are given in Table 1. More details of the assumptions used to derive these values are given in Annex A.

This analysis neglects any delays due to the failure of collision resolution, or errors in the packet data.

3.2 CPCH with code allocation

The model shown in Figure 8, as well as Equation 11, are applicable for CPCH with code allocation.

3.3 CPCH with monitoring of CPCH status using AICH

With current CPCH proposals for determining the availability of channels, the UE would need to monitor activity on the AICH over an extended period. In order to save power this monitoring would only be done after the packet appears at the UE. This delay is shown in Figure 9 as D_{mon}.

It is assumed that monitoring would then continue as a background process, so there is no additional monitoring delay in the event of re-tries after failed access attempts. Figure 9 also shows a delay component D0 which applies in the event that no free channel is found.

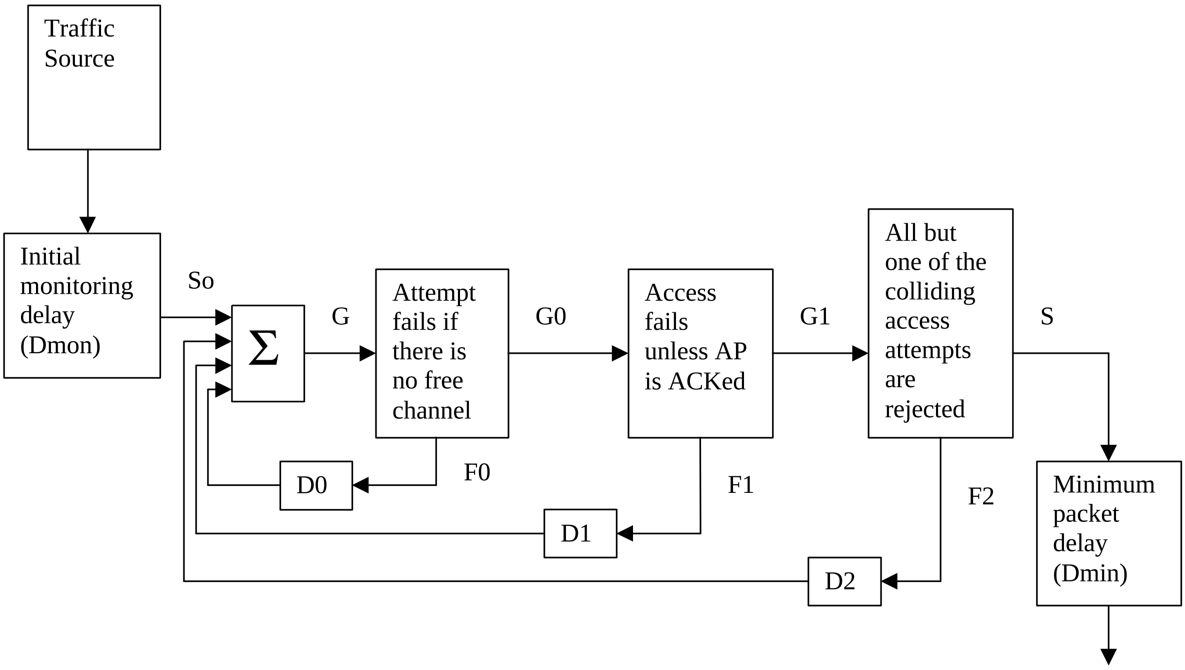

Figure 9: Model for delay calculation for CPCH with monitoring of AICH

Thus, extending Equation 11, the average packet delay can be written as:

Equation 12

$$D_{av-mon} = D_{mon} + D_{\min} + \frac{(F0.D0 + F1.D1 + F2.D2)}{S}$$

3.4 Proposed CPCH

In the enhanced CPCH proposed in [5], the CPCH status is determined from regular broadcast information and an initial monitoring period is not required. Equation 12 still applies but with D_{mon}=0.

3.5 RACH/FACH/DCH

The delay mode for RACH/FACH/DCH packet transmission is shown in Figure 10. Here an additional delay component has been introduced due to failure of the RACH message part. In practice, both failure of the message part and collisions would be resolved by receipt of a transmission on the FACH. This would normally either be a positive or negative acknowledgement, although lack of response on the FACH could also indicate a failure and the need for a re-try.

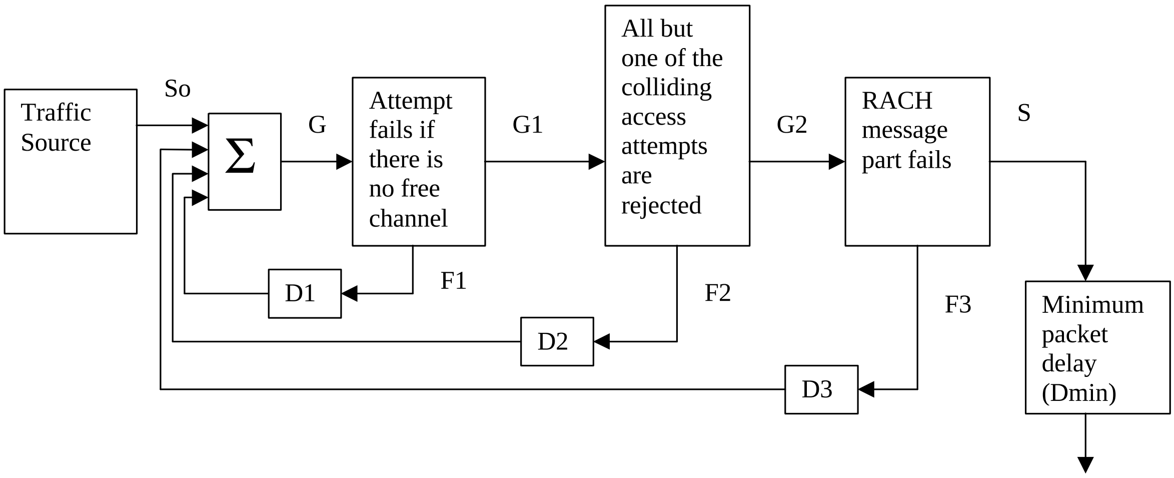

Figure 10: Delay model for RACH/FACH/DCH

Thus the delay for RACH/FACH/DCH is given by

Equation 13

$$D_{av-RACH} = D\min + \frac{(F1.D1 + F2.D2 + F3.D3)}{S}$$

3.6 Delay Parameters

Using the above equations the average packet delay can be computed as a function of the access rate G, and hence as a function of throughput S. However, values are needed for the various delay parameters. These are derived in Annex A and shown in Table 1. It should be emphasised that the values here are intended to be average values.

CPCH proposal	Dmin (ms)	Dmon (ms)	D0 (ms)	D1 (ms)	D2 (ms)	D3 (ms)
Current CPCH (no monitoring)	47.3	-		12	16	-
Current CPCH (perfect monitoring)	47.3	30	0.7	12	16	-
Possible CPCH (Code allocation, no monitoring)	47.3	-	-	12	16	-
Proposed CPCH (Code allocation and monitoring)	53.3	-	6	18	22	-
RACH/FACH/DCH	90	-	-	17.3	58.7	58.7

Table 1: Delay parameters assumed for CPCH options

The values in the table do not include the effect of any significant random back-off period and so may be considered optimistic. The relatively small values of D0 to D3 imply that the access failure rate must become quite high in order for the average delay to increase significantly above Dmin + Dmon.

3.7 Delay Results

The above analysis gives us results for throughput and delay for packet transmission in the following cases (with 16 CPCH's or 16 DCH's in the case of RACH/FACH/DCH):

1. Current CPCH with no monitoring of status
2. Current CPCH with ideal monitoring of CPCH status from AICH
3. Possible CPCH with code allocation and no monitoring of CPCH status
4. Proposed CPCH in [5] with code allocation and ideal CPCH status monitoring
5. RACH/FACH/DCH

Results are shown in Figure 11.

It can be seen that for low loads the packet delay is dominated by the minimum delay. This is smallest for the CPCH schemes without monitoring. The monitoring method for the current CPCH, which is based on observing activity on the AICH, imposes a significant delay. The value used here may even be an underestimate. The minimum delay for the RACH scheme is governed mainly by the time needed for a response from higher layers on the FACH, and is therefore much higher than that achieved by CPCH.

The CPCH without monitoring shows steadily increasing delay with throughput. The other schemes typically show a well defined "knee" at about 0.9 of maximum throughput, where the access failure rate becomes significant.

CPCH with code allocation (and no monitoring) gives the lowest delay at all throughput levels. The modified CPCH scheme proposed in [5] has slightly higher delay, arising from the extra time needed to read the broadcast CPCH status.

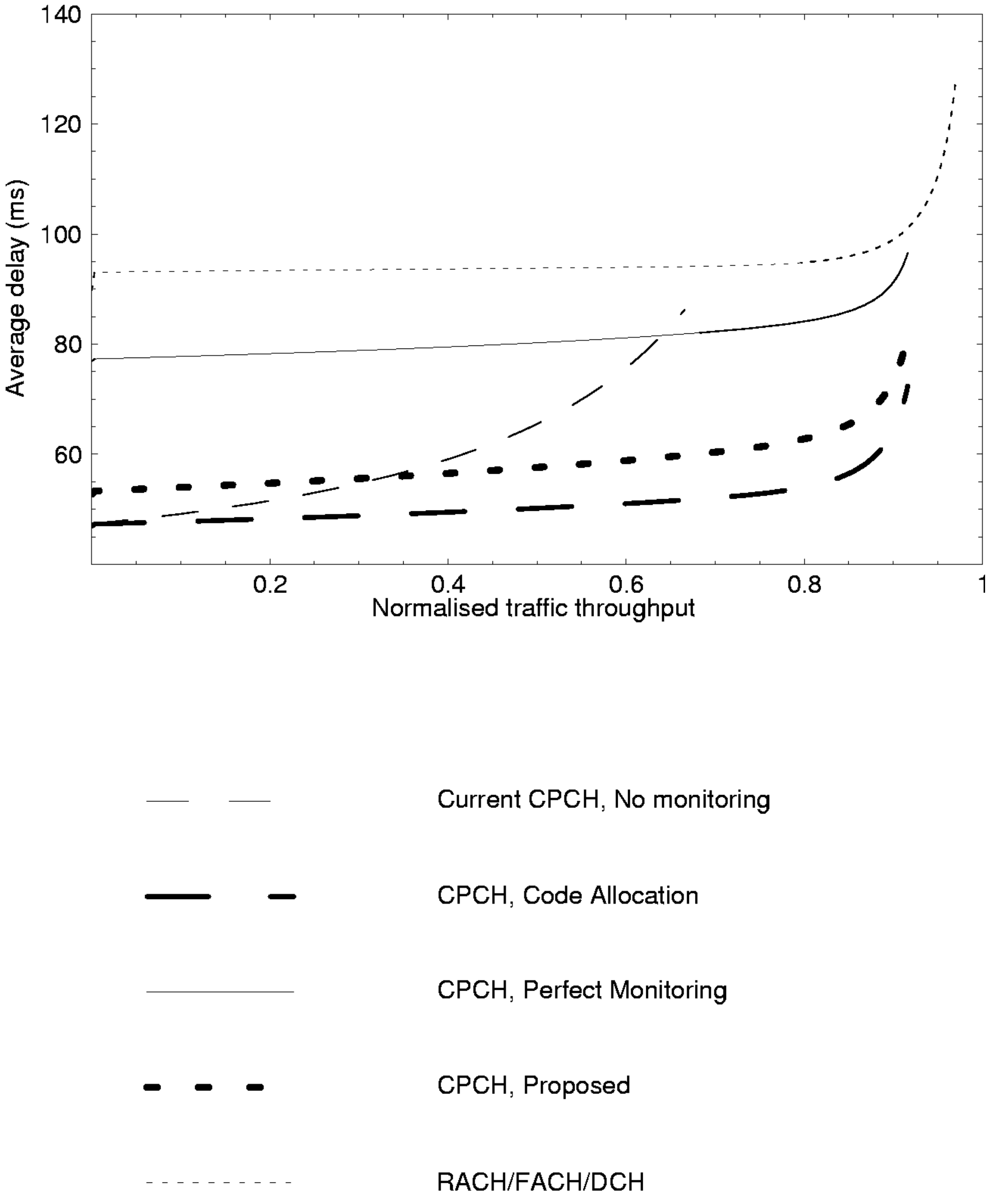

Figure 11: Average delay as a function of throughput for various packet transmission schemes (16 signatures, 16 channels, 30ms packet duration)

4. Conclusions

These conclusions are mainly based on results obtained for a fully loaded CPCH system using 16 signatures and 16 CPCH channels with 30ms packet duration (including power control preamble). According to current assumptions this seems to be the worst case in terms of access rate.

The results presented here show that the in the current proposals for CPCH [1,2,3] the ability of the UE to monitor the status of the CPCH is essential to achieving good results in terms of minimising the access rate needed to support a given throughput (see Figure 5).

The introduction of code allocation at the end of the collision resolution phase as proposed in [4], also allows high throughput. This scheme also significantly reduces the collision rate (see Figure 7). It should also be noted that using CPCH status monitoring (by any method), without channel allocation, leads to a relatively high collision failure rate.

Results are also presented for the use of RACH to set up a DCH for packet transmission. Performance is better than CPCH in terms off access rate and collision failure rate, but poorer in terms of average delay. However, comparing results for CPCH and RACH in Figure 5 suggests that the current constraint in CPCH of allocating only one channel per access slot is not a significant limitation on performance. This limit does not apply for RACH.

The performance results for a proposed enhancement to CPCH [5] are also presented. This combines both low overhead CPCH status monitoring and code allocation. Transmission delay, collision failure rate and access rate vs throughput compare favourably with the other options considered.

5. References

1. TSGR1#7(99)A72, “Proposed CPCH-related insertions into 25.213 (Resubmission)”, Adhoc 14
2. TSGR1#7(99)A73, “Proposed CPCH-related insertions into 25.214 (Resubmission)”, Adhoc 14
3. TSGR1#7(99)A74, “Proposed CPCH-related insertions into 25.211 (Resubmission)”, Adhoc 14
4. TSGR1#6(99)906, “Enhanced CPCH procedure”, Samsung
5. TSGR1#7(99)b37, “Enhanced CPCH with status monitoring and code assignment”, Philips
6. TSGR1#7(99)b38, “Status information for CPCH”, Philips

ANNEX A : Delay Parameters for Packet Transmission

Here we give indicate the assumptions used in deriving delay values for the various packet transmission options. The slots mentioned here are 10/15 ms.

Event	Channel Used	Average Time Elapsed (slots)	Minimum Time	Maximum Time	Comments
Packet ready					
Select Access slot (Random back-off)		8	1	15	Minimum time allows some processing delay
Send CPCH Access preamble	Access preamble	2	2	2	Assume all sub-channels are available
Wait for ACK (including power ramping)		6	0	Tramp	Assume AICH timing =0, and two preamble tx's needed on average for power ramping
Receive ACK	CP-AICH	2	2	2	
UE Processing		2	2	2	
Send CR preamble	CR preamble	2	2	2	
Receive CR ACK	CR-AICH	2	2	2	
Wait to start packet		2	2	2	
Power control preamble	DPCCH/ CPCH	15	15	15	
Send packet	DPCCH/ CPCH	30	30	Tpacket	Shortest packet assumed to be 20ms
Total Time (slots)		71	58	42 +Tramp +Tpacket	
Total Time (ms)		47.3	38.7		

Table 2: Delay for current CPCH packet transmission (with no status monitoring)

Dmin	71slots (47.3ms)	Average delay with no failed access attempts
D1	18slots (12ms)	No ACK after Access Preamble
D2	24slots (16ms)	No ACK after Collision Resolution

The same values apply for CPCH with code allocation.

Event	Channel Used	Average Time Elapsed (slots)	Minimum Time	Maximum Time	Comments
Packet ready					
Monitor AICH		45	45	45	Assumed value equal to shortest packet+preamble (30ms)
Select Access slot (Random back-off)		8	1	15	Minimum time allows some processing delay
Send CPCH Access preamble	Access preamble	2	2	2	Assume all sub-channels are available
Wait for ACK (including power ramping)		6	0	Tramp	Assume AICH timing =0, and two preamble tx's needed on average
Receive ACK	CP-AICH	2	2	2	
UE Processing		2	2	2	
Send CR preamble	CR preamble	2	2	2	
Receive CR ACK	CR-AICH	2	2	2	
Wait to start packet		2	2	2	
Power control preamble	DPCCH/ CPCH	15	15	15	
Send packet	DPCCH/ CPCH	30	30	Tpacket	Shortest packet assumed to be 20ms
Total Time (slots)		116	103	87 +Tramp +Tpacket	
Total Time (ms)		77.3	68.7		

Table 3: Delay for current CPCH packet transmission (with AICH monitoring)

Dmin	71slots (47.3ms)	Average delay with no failed access attempts, less Dmon
Dmon	45slots (30ms)	Initial monitoring delay
D0	1 slot (7ms)	No channel available from monitoring
D1	18slots (12ms)	No ACK after Access Preamble
D2	24slots (16ms)	No ACK after Collision Resolution

Event	Channel Used	Average Time Elapsed (slots)	Minimum Time	Maximum Time	Comments
Packet ready					
Wait for CPCH status		8	1	15	
Read CPCH status	PICH	1	1	1	
Select Access slot (Random back-off)		8	1	15	Minimum time allows some processing delay
Send CPCH Access preamble	Access preamble	2	2	2	Assume all sub-channels are available
Wait for ACK (including power ramping)		6	0	Tramp	Assume AICH timing =0, and two preamble tx's needed on average
Receive ACK	CP-AICH	2	2	2	
UE Processing		2	2	2	
Send CR preamble	CR preamble	2	2	2	
Receive CR ACK	CR-AICH	2	2	2	
Wait to start packet		2	2	2	
Power control preamble	DPCCH/ CPCH	15	15	15	
Send packet	DPCCH/ CPCH	30	30	Tpacket	Shortest packet assumed to be 20ms
Total Time (slots)		80	60	58 +Tramp +Tpacket	
Total Time (ms)		53.3	40		

Table 4: Delay for enhanced CPCH packet transmission (CPCH status on PICH)

Dmin	80 slots (53.3ms)	Average delay with no failed access attempts
D0	9 slots (6ms)	No channel available from status monitoring
D1	27 slots (18ms)	No ACK after Access Preamble
D2	33 slots (22ms)	No ACK after Collision Resolution

Event	Channel Used	Average Time Elapsed (slots)	Minimum Time	Maximum Time	Comments
Packet ready					
Dynamic persistence delay		8	1	Tpers	Value assumed
Select Access slot (Random back-off)		8	1	15	Assume all sub-channels are available
Send RACH Access preamble	Access preamble	2	2	2	
Wait for ACK (including power ramping)		6	0	Tramp	Assume AICH timing =0, and two preamble tx's needed on average
Receive ACK	AICH	2	2	2	
Wait to start packet		2	2	2	
Send RACH message part	PRACH	15	15	15	
Wait for higher layers		30	30	30	
Send DCH allocation	FACH	15	15	15	
Wait to start DCH		2	2	2	
Power control preamble	DCH	15	15	15	
Send packet	DCH	30	30	Tpacket	Shortest packet assumed to be 20ms
Total Time (slots)		135	60	81 +Tpers +Tramp +Tpacket	
Total Time (ms)		90	85		

Table 5: Delay for RACH/FACH/DCH packet transmission

Dmin	135 slots (90ms)	Average delay with no failed access attempts
D1	26 slots (17.3ms)	No ACK after Access Preamble
D2	88 slots (58.7ms)	No ACK on FACH (due to collision)
D3	88 slots (58.7ms)	No ACK on FACH (due to failure of message part)

Time to read dynamic persistence parameters from BCH has not been included. It is assumed that if no DCH's are available, then this would be indicated by a NACK in response to the access preamble.

Event	Channel Used	Average Time Elapsed (slots)	Minimum Time	Maximum Time	Comments
Packet ready					
Dynamic persistence delay		8	1	Tpers	Value assumed
Select Access slot (Random back-off)		8	1	15	Assume all sub-channels are available
Send RACH Access preamble	Access preamble	2	2	2	
Wait for ACK (including power ramping)		6	0	Tramp	Assume AICH timing =0, and two preamble tx's needed on average
Receive ACK	AICH	2	2	2	
Wait to start message part		2	2	2	
Send RACH message part	PRACH	15	15	15	
Total Time (slots)		43	23	36 +Tpers +Tramp	
Total Time (ms)		28.7	15.3		

Table 6: Delay for RACH short packet transmission (10ms packet)

This table is only included as background information. As can be seen by comparison with Table 5, the typical delay for a packet sent using the RACH message part is much shorter than using RACH/FACH/DCH. However, there is a limit on packet size.