Supplemental Material

Appendix: Derivation of Average Access Latency and Tuning Time

First, we derive the average access latency given B' and I. Recall that the data access is divided into three phases (Algorithm 1): initial probe (lines 1-7), index search (lines 8-25), and data retrieval (lines 26-30). With an error-free broadcast, the average latency until the moment when the index bucket of the chunk containing the desired data item (termed as the *target index bucket*) is received is $\frac{I}{2}+\frac{I(C-1)}{2}+1=\frac{IC}{2}+1$ buckets. However, if the target index bucket is corrupted, we will have to delay a bcast (i.e., IC buckets) to get its next broadcast instance. In general, assuming a link error probability of p, the probability of the target index bucket being corrupted continuously for i times is $p^i(1-p)$; in this case, an additional delay of $i \cdot IC$ is incurred. Thus, the average access latency for the phases of initial probe and index search is given by:

$$E(d_{pi}) = \frac{IC}{2} + 1 + \sum_{i=0}^{\infty} p^i(1-p) \cdot i \cdot IC = \frac{IC}{2} + 1 + \frac{IC \cdot p}{1-p}. \tag{15}$$

In the phase of data retrieval, if the desired data item is contained in the target index bucket (with a probability of $\frac{B'}{B(I-1)+B'}$), we are done and no additional delay is incurred. Otherwise, the item is in a separate data bucket (with a probability of $\frac{B(I-1)}{B(I-1)+B'}$); the average latency for retrieving the data bucket in an error-free environment is $\frac{I}{2}$, and we will have an additional delay of $i \cdot IC$ if the data bucket is corrupted continuously for i times. The average access latency for this phase is:

$$\begin{aligned} E(d_d) &= 0 \cdot \frac{B'}{B(I-1)+B'} + \big(\frac{I}{2} + \sum_{i=0}^{\infty} p^i(1-p) \cdot i \cdot IC\big) \cdot \frac{B(I-1)}{B(I-1)+B'} \\ &= \big(\frac{I}{2} + \frac{IC \cdot p}{1-p}\big) \cdot \frac{B(I-1)}{B(I-1)+B'}. \end{aligned} \tag{16}$$

Therefore, the average overall access latency is obtained as follows:

$$E(d) = E(d_{pi}) + E(d_d), \tag{17}$$

where $E(t_{pi})$ and $E(d_d)$ are given in (15) and (16), respectively.

Next, we analyze the average tuning time. Suppose the client tunes into the broadcast right before the jth ($1 \leq j \leq I$) bucket of a chunk. The average tuning time until an error-free index bucket is received can be generally expressed by:

$$\sum_{i=0}^{\infty} p^i(1-p) \cdot x_{ij}, \tag{18}$$

where x_{ij} is the tuning time if i sequential buckets are all corrupted. If the $(i+1)$th bucket is an index bucket, we are finished with the initial probe; otherwise it is a data bucket, and we follow its pointer to access the next index bucket, which requires a tuning time of $\frac{1}{1-p}$ on average. Hence, we have

$$x_{ij} = \begin{cases} i+1, & \text{if } i = 1-j, I+1-j, 2I+1-j, \cdots; \\ i+1+\frac{1}{1-p}, & \text{otherwise.} \end{cases} \tag{19}$$

Averaging over all j's ($1 \leq j \leq I$), we get the average tuning time for the initial probe phase:

$$E(t_p) = \sum_{i=0}^{\infty} p^i(1-p) \cdot (i+1) + \frac{I-1}{I} \cdot \sum_{i=0}^{\infty} p^i(1-p) \cdot \frac{1}{1-p} = \frac{2I-1}{I(1-p)}. \tag{20}$$

To analyze the average tuning time for the index search phase, first we derive the tuning time $t(l)$ up to the moment when the target index bucket that is l chunks away is received. This can be computed recursively:

$$t(l) = \begin{cases} 0, & \text{if } l = 0; \\ t(l-x) \cdot (1-p) + t(l-1) \cdot p + 1, & \text{if } l > 0, \end{cases} \tag{21}$$

where x is the maximum value less than or equal to l in the set of $\{1, 2, \lfloor r+2 \rfloor, \cdots, \lfloor \frac{r^{n_c-1}-1}{r-1} \rfloor + 1\}$.

For $l > 0$, it is possible that the received target index bucket is corrupted; in this case, a new round of search (with $C-1$ chunks away from the next target index bucket) is started. If the target index bucket is corrupted continuously for i times, i more rounds of searches are needed. Hence, the overall tuning time is:

$$t(l) + \sum_{i=1}^{\infty} p^i(1-p) \cdot i \cdot t(C-1) = t(l) + \frac{t(C-1) \cdot p}{1-p} \qquad (l > 0) \tag{22}$$

Thus, the average tuning time for index search is given by:

$$E(t_i) = \frac{1}{C}\Big(t(0) + \sum_{l=1}^{C-1} \big(t(l) + \frac{t(C-1) \cdot p}{1-p}\big)\Big). \tag{23}$$

In the data retrieval phase, if the desired data item is contained in the target index bucket, no additional tuning time is incurred. Otherwise, the item is in a separate data bucket; an additional tuning time of $i+1$ buckets is needed if the data bucket is corrupted continuously for i times. The average tuning time for this phase is obtained as follows:

$$\begin{aligned} E(t_d) &= 0 \cdot \frac{B'}{B(I-1)+B'} + \big(\sum_{i=0}^{\infty} p^i(1-p)\cdot(i+1)\big) \cdot \frac{B(I-1)}{B(I-1)+B'} \\ &= \frac{B(I-1)}{(B(I-1)+B')\cdot(1-p)}. \end{aligned} \tag{24}$$

The average overall tuning time is thus given by:

$$E(t) = E(t_p) + E(t_i) + E(t_d), \tag{25}$$

where $E(t_p), E(t_i)$, and $E(t_d)$ are obtained in (20), (23), and (24), respectively.