TAMUNA: Doubly Accelerated Federated Learning with Local Training, Compression, and Partial Participation

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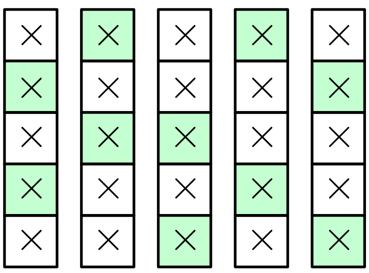
TAMUNA

input: stepsizes $\gamma > 0$, $\eta > 0$;
number of participating clients $c \in \{2, \dots, n\}$
sparsity index $s \in \{2, \dots, n\}$ for compression
initial model estimate $\bar{x}^0 \in \mathbb{R}^d$
initial control variates $h_i^0 \in \mathbb{R}^d$ s.t. $\sum_{i=1}^n h_i^0 = 0$
for $r = 0, 1, \dots$ (rounds) **do**
  choose a subset $\Omega^r \in [n]$ of size c
  choose the number of local steps L^r
  for clients $i \in \Omega^r$, in parallel, **do**
    $x^{r,0} := \bar{x}^r$
    for $l = 0, \dots, L^r$ **do**
      $x_i^{r,l} := x_i - \gamma g_i^{r,l} + \gamma h_i^r$ with $g_i^{r,l} \approx \nabla f_i^t(x_i^{r,l})$
    end for
    send $v_i^r := \mathcal{C}_i^r(x_i^{r,L^r})$ to server   // uplink comm.
  end for
  at server: $\bar{x}^{r+1} := \frac{1}{s} \sum_{i \in \Omega^r} v_i^r$ // model update
  $\bar{x}^{r+1}$ is sent to clients $i \in \Omega^r \cup \Omega^{r+1}$ // downlink comm.
  for clients $i \in \Omega^r$, in parallel, **do**   // update of control variates
    $h_i^{r+1} := h_i^r + \frac{\eta}{\gamma}\left(\mathcal{C}_i^r(\bar{x}^{r+1}) - v_i^r\right)$
  end for
  for clients $i \notin \Omega^r$, in parallel, **do**
    $h_i^{r+1} := h_i^r$ // idle clients
  end for
end for



$\mathcal{C}_i^r$: random selectors with
- s (=2) comm. values per coordinate
- $\leq \lceil \frac{sd}{c} \rceil$ (=2) comm. values per active client

With $\gamma \approx \frac{1}{L}$, $s \approx \max\left(2, \frac{c}{d}, \alpha c\right)$, $L^r \approx \max\left(\sqrt{\frac{s\kappa}{n}}, 1\right)$, $\eta \approx \frac{1}{2L^r}$, $g_i = \nabla f_i$, TotalCom (= UpCom + α.DownCom) complexity of TAMUNA in #floats:

$$\mathcal{O}\left(\left(\sqrt{d}\sqrt{\kappa}\sqrt{\frac{n}{c}} + d\sqrt{\kappa}\frac{\sqrt{n}}{c} + d\frac{n}{c} + \sqrt{\alpha}\, d\sqrt{\kappa}\sqrt{\frac{n}{c}}\right)\log \epsilon^{-1}\right)$$

→ New SOTA with double acceleration

Distributed optimization with n clients + server:

$$\underset{x \in \mathbb{R}^d}{\text{minimize}}\ f(x) := \frac{1}{n}\sum_{i=1}^n f_i(x)$$

Every f_i is $\mathcal{L}$-smooth and μ-strongly convex. $\kappa := \frac{\mathcal{L}}{\mu}$

Algorithms with Local Training (LT) or Compressed Communication (CC), in case of full participation:

Algorithm	LT	CC	uplink comm.
DIANA	✗	✓	$\tilde{\mathcal{O}}((1+\frac{d}{n})\kappa + d)$
EF21	✗	✓	$\tilde{\mathcal{O}}(d\kappa)$
Scaffold	✓	✗	$\tilde{\mathcal{O}}(d\kappa)$
FedLin	✓	✗	$\tilde{\mathcal{O}}(d\kappa)$
S-Local-GD	✓	✗	$\tilde{\mathcal{O}}(d\kappa)$
Scaffnew	✓	✗	$\tilde{\mathcal{O}}(d\sqrt{\kappa})$
5GCS	✓	✗	$\tilde{\mathcal{O}}(d\sqrt{\kappa})$
FedCOMGATE	✓	✓	$\tilde{\mathcal{O}}(d\kappa)$
TAMUNA	✓	✓	$\tilde{\mathcal{O}}\left(\sqrt{d}\sqrt{\kappa} + d\frac{\sqrt{\kappa}}{\sqrt{n}} + d\right)$

(full participation: TAMUNA reverts to CompressedScaffnew [Condat et al. 2022])

Algorithms with LT or CC, and allowing for Partial Participation:

Algorithm	LT	CC	uplink communication
DIANA-PP	✗	✓	$\tilde{\mathcal{O}}((1+\frac{d}{c})\kappa + d\frac{n}{c})$
Scaffold	✓	✗	$\tilde{\mathcal{O}}(d\kappa + d\frac{n}{c})$
5GCS	✓	✗	$\tilde{\mathcal{O}}\left(d\sqrt{\kappa}\sqrt{\frac{n}{c}} + d\frac{n}{c}\right)$
TAMUNA	✓	✓	$\tilde{\mathcal{O}}\left(\sqrt{d}\sqrt{\kappa}\sqrt{\frac{n}{c}} + d\sqrt{\kappa}\frac{\sqrt{n}}{c} + d\frac{n}{c}\right)$