The major challenge: the difficulty of improving application scalability with conventional techniques.

One of the solutions: prefetching data before its actual access is executed.

The generic prefetching scheme proposed in HPX, which results in:
- improving the parallel performance by leveraging the abstraction capabilities,
- utilizing asynchronous task-based execution flow,
- exploiting execution policies for the fine-grained control.

### Results

```python
onto ctx = hpx::parallel::make_prefetcher_context
    loop_range.begin(), loop_range.end(),
    prefetch_distance_factor, container_1, container_2, ..., container_n,
    hpx::parallel::for_each(policy,
    ctx.begin(), ctx.end()),
    [4][ord::size_t i]
    container_1[i] = ...
    container_2[i] = ...
    ...
    container_n[i] = ...
); ```

Figure 2: The prefetching method used in for_each

Figure 3: The data transfer rate of for_each with the standard random access iterator versus prefetching iterator

### HPX Data Prefetching Iterator

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**Abstract**

### Introduction

Data prefetching methods:
- Hardware prefetching method: predicting the future cache misses by using the past access pattern with considering the data stream.
- Software prefetching method: prefetching data before the execution of its actual access by using the prefetch directives into the code.
- Thread based prefetching method: executing code in the prefetcher thread context and bringing the data of the next cache line into the shared cache before the main thread accesses it:
  - Precomputing the load addresses accurately.
  - Following more complex pattern compared to the other methods.

However, scaling can be degrade with
- Thread based prefetching: Cache misses, Global barriers and Resource competition.
- The cache prefetcher used in HPX aids prefetching that
  - reduces the memory accesses latency, and
  - inhibits the global barrier.

- **for_each** helps creating sufficient parallelism by determining the number of the iterations to run on each HPX thread.
- HPX threads makes the invocation of the loop asynchronous, while the data of all containers within the loop of the next step is prefetched in each iteration.
- HPX is able to prefetch data in sequential or in parallel with applying an execution policy.
- HPX prefetcher works with any data type of the containers and even if each container has different data type.

### Prefetching Iterator Implemented in HPX

- **for_each** is one of the HPX parallel algorithms used to evaluate the proposed prefetching method.
- Data of the next iteration step is prefetched in the cache memory with the prefetching iterator called in each iteration within the **for_each**.
- HPX combines prefetching method with the asynchronous task execution by providing a new future instance representing the result of the function execution (Figure 1).
- The program execution is divided into several chunks within **for_each** (Figure 2) and its iterator is developed to prefetch the data of the next chunk size in either sequential or in parallel.
- The prefetching iterator is initialized in **make_prefetcher_context** and it executes with **ctx.begin()**.
- ctx is the struct that references to all container in the
- The distance between each two prefetching operations is computed based on the value of **prefetch_distance_factor**, which is the factor of the length of the cache line.

### Experimental Results

In an N-Body problem, there are N particles moving under the influence of the gravitational attraction. Prefetching iterator increases bandwidth vs. standard random access iterator by 30% on average using two NUMA domains with 8 threads each (figure 3).

The results of the performance of the prefetching iterator with different **prefetch_distance_factor** are shown in figure 4 and 5 for 1 and 2 NUMA domains respectively:
- For the large distance, data prefetching cannot improve the parallel performance.
- Very small prefetcher distances make more data to be prefetched, which become more expensive and dominate the gains from prefetching.

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